

NOTICE

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TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	CRA Scope.....	2
1.2	Technical Approach.....	2
2.0	HUMAN HEALTH SITE CONCEPTUAL MODEL	3
2.1	Receptors.....	5
2.2	Human Health Exposure Scenarios	5
2.2.1	Wildlife Refuge Worker Exposure Scenario	6
2.2.2	Wildlife Refuge Visitor Exposure Scenario.....	8
3.0	DATA COLLECTION AND EVALUATION.....	10
3.1	Human Health Risk Assessment Data Quality Objectives	10
3.1.1	Step 1: State the Problem.....	11
3.1.2	Step 2: Identify the Decision.....	11
3.1.3	Step 3: Identify the Inputs to the Decision.....	11
3.1.4	Step 4: Define Study Boundaries.....	12
3.1.5	Step 5: Identify the Data Adequacy Decision Rules.....	12
3.1.6	Step 6: Specify Tolerable Limits on Decision Errors	15
3.1.7	Step 7: Optimize the Design	15
4.0	EXPOSURE ASSESSMENT	15
4.1	Exposure Factors.....	15
4.1.1	Exposure Pathway Assessment.....	15
4.1.2	WRW Scenario Exposure Factors.....	16
4.1.3	WRV Scenario Exposure Factors	18
4.2	Functional EUs and AOCs.....	19
4.2.1	EU Development.....	19
4.2.2	Defining and Assessing EUs.....	20
4.2.3	EUs for the Wildlife Refuge Worker	26
4.2.4	EUs for the Wildlife Refuge Visitor	26
4.2.5	Defining and Assessing AOCs.....	27
4.3	Data Aggregation for Risk Assessment.....	27
4.4	COC Identification and Selection	28
4.4.1	Selection of EU and AOC COCs	28
4.4.2	Data Quality Assessment	30
4.4.3	Data Aggregation	30
4.4.4	Elimination of Essential Nutrients/Major Cations and Anions.....	30
4.4.5	PRG Screen	30
4.4.6	Detection Frequency Filter.....	30
4.4.7	Data Distribution Testing.....	31
4.4.8	Background Analysis	31
4.4.9	Professional Judgment	32
4.4.10	Presentation of COCs.....	32
4.5	Pathway Significance Evaluations.....	33
4.5.1	Groundwater-to-Surface Water Pathway	33
4.5.2	Groundwater/Subsurface Soil-to-Air Pathway	34
4.6	Exposure Point Concentrations.....	34

4.6.1	Intake Calculations.....	35
5.0	HUMAN HEALTH TOXICITY ASSESSMENT	37
5.1	Identification of Toxicity Values for Carcinogenic Effects.....	38
5.1.1	Chemical Carcinogens	38
5.1.2	Radionuclides.....	39
5.2	Identification of Toxicity Values for Noncarcinogenic Effects.....	39
5.3	Dermal Exposure to Chemicals	40
5.4	Identification of Radionuclide Dose Conversion Factors	40
6.0	HUMAN HEALTH RISK CHARACTERIZATION PERFORMED ON AN EU AND AOC BASIS	48
6.1	Calculating and Characterizing Carcinogenic Effects	48
6.2	Calculating and Characterizing Noncarcinogenic Effects	49
6.3	Dermal Assessment.....	51
6.4	Calculating and Characterizing Radiation Dose	51
6.5	Conducting an Uncertainty Analysis	52
7.0	ECOLOGICAL RISK ASSESSMENT	53
7.1	Use of Watershed ERA in CRA.....	55
7.2	CRA Background, Site Conceptual Model, and Data Quality Objectives	56
7.2.1	Environmental Setting	56
7.2.2	Site Conceptual Model.....	57
7.2.3	Ecological Risk Management Goals and Assessment Endpoints	59
7.2.4	Data Quality Objectives.....	60
7.2.5	Data Types and Adequacy	62
7.2.6	Ecological PRGs	62
7.3	Sitewide ECOC Identification Process	63
7.4	Risk Analysis Process	66
7.4.1	Exposure Units.....	67
7.4.2	Risk Analysis Process for Non-PMJM Receptors	67
7.4.3	Risk Analysis Process for PMJM Receptor	70
7.4.4	Ecological Risk Characterization and Uncertainty	70
8.0	COMPREHENSIVE RISK ASSESSMENT REPORT ORGANIZATION.....	75
9.0	REFERENCES	76

LIST OF TABLES

Table 4.1	CRA Exposure Factors for the On-Site Wildlife Refuge Worker Receptor.....	17
Table 4.2	CRA Exposure Factors for the Wildlife Refuge Visitor Receptor	18
Table 4.3	Areas of the RFETS EUs.....	24
Table 4.4	Time-Weighted Average Activity Areas for Wildlife Refuge Workers.....	25
Table 4.5	Data Aggregation for the CRA	28
Table 4.6	Rationale for Selecting COCs.....	33
Table 4.7	Intake Equations for the WRW.....	36
Table 4.8	Intake Equations for the WRV.....	37
Table 5.1	Carcinogen Groups	39
Table 5.2	Nonradiological Toxicity Constants	41
Table 5.3	Radiological Toxicity Constants.....	47

LIST OF FIGURES

Figure 1.1	CRA Process.....	4
Figure 2.1	Human Health Site Conceptual Model.....	7
Figure 4.1	Human Health Exposure Units.....	21
Figure 4.2	Exposure Unit Map With IHSSs	22
Figure 4.3	Exposure Unit Map With PACs	23
Figure 4.4	EU/AOC COC Selection Process.....	29
Figure 7.1	Sequence of Activities for Ecological Risk Assessment.....	54
Figure 7.2	Ecological Site Conceptual Model	58
Figure 7.3	Sitewide ECOC Screening Process	65
Figure 7.4	CRA Risk Analysis for the Non-PMJM Receptor	69
Figure 7.5	CRA Risk Analysis Process for the PMJM Receptor	72
Figure 7.6	PMJM Habitat Map	73
Figure 7.7	RFETS Vegetation Map	74

APPENDICES

Appendix A – Preliminary Remediation Goals

ACRONYMS

95UCL	upper confidence limit at a 95 percent level
AF	absorption factor
AI	adequate intake
AL	action level
ALF	Action Levels and Standards Framework for Surface Water, Ground Water, and Soils
ANOVA	analysis of variance
AOC	Area of Concern
AUF	area use factor
BAF	bioaccumulation factor
BD	building debris
BZ	Buffer Zone
BZSAP	Buffer Zone Sampling and Analysis Plan
CAD/ROD	Corrective Action Decision/Record of Decision
CAS	Chemical Abstract Service
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm ²	square centimeter
cm/hr	centimeter per hour
CMS	Corrective Measures Study
COC	contaminant of concern
CRA	Comprehensive Risk Assessment
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CRQL	contract-required quantitation limit
CSF	cancer slope factor
CHWA	Colorado Hazardous Waste Act

ACRONYMS, cont.

CWQS	Colorado State Water Quality Standard
DAD	dermally absorbed dose
DBP	di-n-butyl phthalate
DCF	dose conversion factor
DER	duplicate error ratio
DOE	U.S. Department of Energy
DQF	Data Quality Filter
DQA	Data Quality Assessment
DQO	data quality objective
DRI	daily reference intake
ECOC	ecological contaminant of concern
EcoSSL	ecological soil screening level
EG&G	EG&G Rocky Flats, Inc.
Eh	reduction-oxidation potential
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ERAM	Ecological Risk Assessment Methodology
EU	exposure unit
FS	Feasibility Study
ft ²	square foot
FY	fiscal year
GIS	Geographic Information System
h	hour
HEAST	Health Effects Assessment Summary Tables
HEC6-T	sedimentation in stream networks
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IA	Industrial Area

ACRONYMS, cont.

IA Strategy	Industrial Area Characterization and Remediation Strategy
IAEA	International Atomic Energy Agency
IASAP	Industrial Area Sampling and Analysis Plan
ICRP	International Commission on Radiological Protection
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
IMP	Integrated Monitoring Plan
IR	ingestion rate
IRIS	Integrated Risk Information System
kg	kilogram
kg/mg	kilograms per milligram
K-H	Kaiser-Hill Company, L.L.C.
km	kilometer
L/1,000 cm ³	liters per 1,000 cubic centimeters
L/day	liters per day
LHSU	lower hydrostratigraphic unit
LOAEL	lowest observed adverse effect level
µg/kg	micrograms per kilogram
µm	micron
µg/m ³	micrograms per cubic meter
m	meter
m ²	square meter
m ³ /day	cubic meters per day
MARSSIM	Multi-Agency Radiological Survey and Site Investigation Manual
MDL	method detection limit
mg	milligram
mg/cm ²	milligrams per square centimeter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m ³	milligrams per cubic meter
mg/vol	milligrams per volume

ACRONYMS, cont.

mrem	millirem
mrem/pCi	millirems per picocurie
mrem/pCi/g	millirems per picocurie per gram
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCRP	National Council on Radiation Protection and Measurement
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
OU	Operable Unit
PAC	Potential Area of Concern
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential contaminant of concern
PEC	probable effects level
pH	hydrogen ion activity
PMJM	Preble's meadow jumping mouse
PP	Proposed Plan
PQL	practical quantitation limit
PRG	preliminary remediation goal
QA	quality assurance
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RDA	recommended daily allowance
RDI	recommended daily intake
RfC	Reference Concentration
RFCA	Rocky Flats Cleanup Agreement
RfD	reference dose

ACRONYMS, cont.

RFETS or Site	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RL	reporting limit
RMA	Rocky Mountain Arsenal
RME	reasonable maximum exposure
ROC	receptor of concern
RPD	relative percent difference
RSAL	radionuclide soil action level
SAP	Sampling and Analysis Plan
SCM	Site Conceptual Model
SCMTM	Sitewide Conceptual Model Technical Memorandum
SLERA	screening-level ecological risk assessment
SMDP	scientific management decision point
SQG	sediment quality guideline
SQV	sediment quality value
SSV	soil screening value
SVOC	semivolatile organic compound
SWD	Soil/Water Database
TEC	threshold effects level
TM	Technical Memorandum
TRV	toxicity reference value
TSS	total suspended solids
UBC	Under Building Contamination
UCL	upper confidence limit
UHSU	upper hydrostratigraphic unit
UL	upper limit daily nutrient intake
USFWS	U.S. Fish and Wildlife Service
UTL	upper tolerance limit
VOC	volatile organic compound

ACRONYMS, cont.

vol/day	volumes per day
V&V	verification and validation
WEPP	Watershed Erosion Prediction Project
WRV	wildlife refuge visitor
WRW	wildlife refuge worker
yr/pCi/g	years per picocurie per gram

1.0 INTRODUCTION

This document was prepared under Task 8, Prepare the Comprehensive Risk Assessment Work Plan, of the Final Work Plan for the Development of the Remedial Investigation and Feasibility Study (RI/FS) Report (DOE 2002a). This document describes the scope, activities, and methodology for the Draft Comprehensive Risk Assessment (CRA). The Draft CRA is referred to hereafter as the CRA. The purpose of the CRA is to assess human health and ecological risks posed by chemicals, metals, and radionuclides remaining at the Rocky Flats Environmental Technology Site (RFETS or Site) following accelerated actions. The CRA will support the RI/FS Detailed Analysis of Alternatives, Proposed Plan (PP), and Corrective Action Decision/Record of Decision (CAD/ROD) for the Site.

The tasks associated with this methodology have evolved since the publication of the RI/FS Work Plan. Task 8 of the work plan mentions 10 tasks associated with the CRA Methodology:

1. Data quality objectives;
2. Site Conceptual Model (SCM), including exposure scenarios, exposure pathways, and receptors;
3. Final list of contaminants of concern (COCs) following statistical evaluation and preliminary screening;
4. Reasonably foreseeable anticipated land use and use restrictions for the Site;
5. Background concentrations for COCs;
6. Established detection limits for COCs;
7. COC physical and chemical characteristics;
8. Methods for conducting the exposure assessment, toxicity assessment, and the risk characterization;
9. Fate and transport models used to predict exposure point concentrations (EPCs);
10. Calculated preliminary remediation goals (PRGs) for surface soil, sediments; and groundwater from a human health and ecological perspective.

Tasks 1, 2, 4, 8, and 10 are addressed directly in this methodology. Tasks 3, 5, and 7 will be completed using methods discussed herein and reported in the CRA. Task 6 was included in the Industrial Area (IA) and Buffer Zone (BZ) Sampling and Analysis Plans (SAPs) (DOE 2001; 2002c). Task 9 is discussed below in general and will be presented in depth in a separate groundwater modeling report. Ecological PRGs will be developed and incorporated into Appendix N of Appendix 3 of the Rocky Flats Cleanup Agreement (RFCA) (DOE et al. 1996 [as modified]). Other screening levels developed specifically for the CRA will be included in this Methodology.

1.1 CRA Scope

Scope: The CRA will quantify and report risks posed by residual contamination at the Site to human and ecological receptors after accelerated actions.

RFCA adopted an accelerated action cleanup approach to expedite remedial work and maximize early risk reduction at the Site, as described in RFCA paragraph 79 (DOE et al. 1996). The CRA will be conducted in a progressive approach as accelerated actions are completed and data on the nature and extent of contamination are collected during the Sitewide RI/FS effort. After accelerated actions, the need for further actions, if any, will be analyzed in the Draft RI/FS, hereafter referred to as the RI/FS. Risks to human and ecological receptors posed by residual contamination at the Site will be quantified and evaluated in the CRA. The CRA will be included in the RI/FS Report.

A primary task associated with the CRA is the development of the Final CRA Work Plan and Methodology, hereafter referred to as the CRA Methodology. This CRA Methodology presents the approach and methods to be used in the CRA and documents the SCM, exposure scenarios, exposure factors, toxicity assessment, and risk characterization. The CRA Methodology is a major revision to and supersedes the previously circulated Draft Methodology (DOE 2000), the revision is required due to the change of the reasonably anticipated future use of RFETS as a wildlife refuge as designated by the Rocky Flats National Wildlife Refuge Act of 2001. This designation means that it is unlikely that RFETS would be used for limited industrial, unrestricted open space, or onsite residential uses.

The CRA will address all areas within the RFETS boundary with one exception. Operable Unit (OU) 3, Offsite Areas, will not be included in the CRA because a risk assessment was performed (DOE 1996a) and a CAD/ROD for OU 3 was issued (DOE 1997). Areas to be addressed within the RFETS boundary include those areas containing existing or former OU designations. While CAD/RODs have been issued for some of these OUs (OU 1, OU 11, OU 15, and OU 16), these areas are included to simplify the analysis process and enable a comprehensive risk assessment for each designated exposure unit (EU) within the RFETS boundary.

1.2 Technical Approach

The primary tasks required to complete the CRA, and their interrelationships, are detailed in this section. Figure 1.1 depicts the overall technical approach and sequence of tasks, including the evaluation of additional data if required.

Primary tasks include the following:

- Generate the SCMs for both human health and ecological assessments with all defined exposure pathways, receptors, and scenarios;
- Identify exposure factors;

- Develop EUs; and
- Further refine and develop PRGs or screening levels for the CRA.

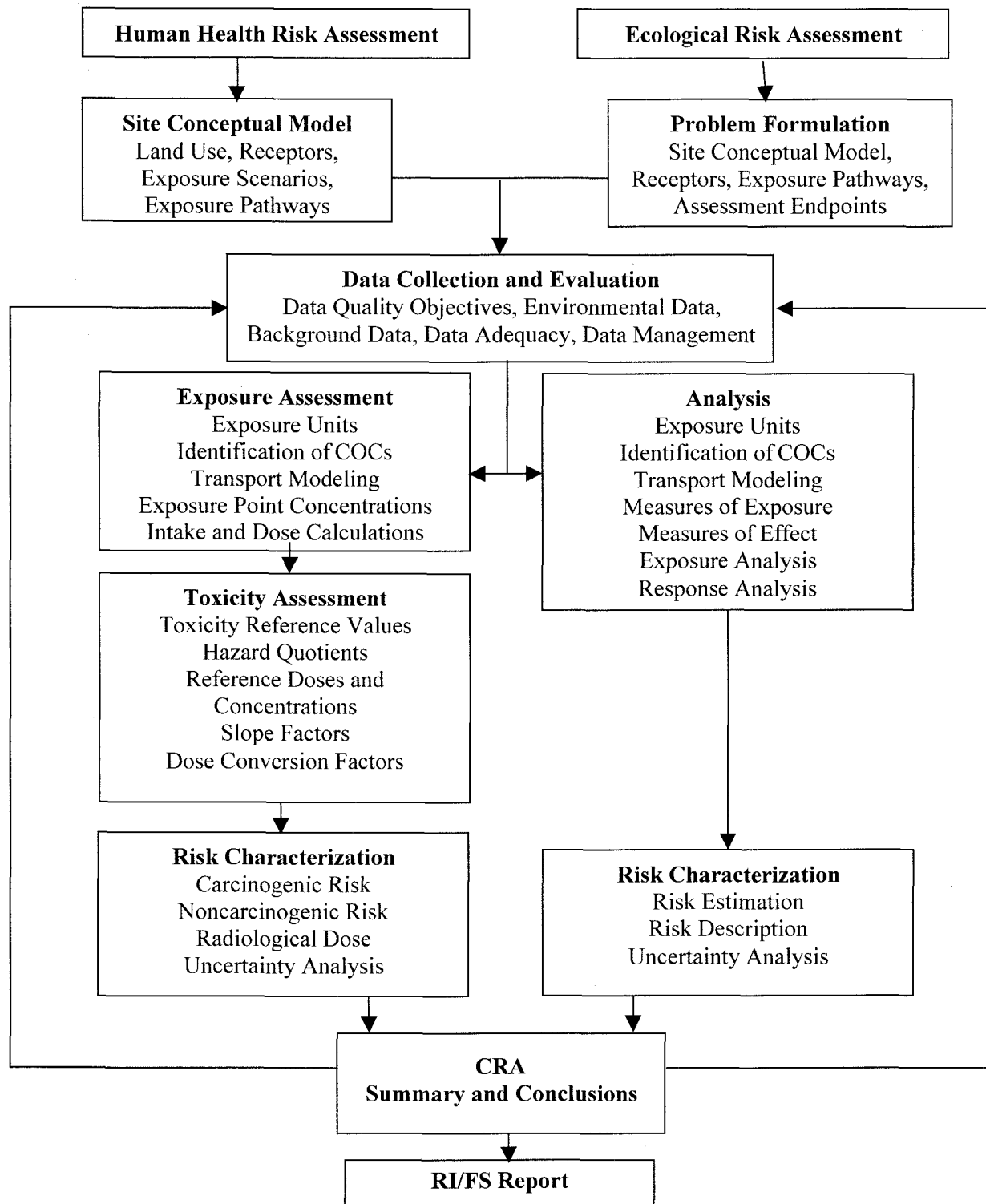
The human health risk assessment (HHRA) and ecological risk assessment (ERA) will be conducted in parallel. The CRA will assess residual contamination using confirmation sampling results.

2.0 HUMAN HEALTH SITE CONCEPTUAL MODEL

Action: Develop a SCM of receptors, exposure scenarios, and exposure pathways to guide the CRA process.

The reasonably anticipated future land use for RFETS is a wildlife refuge. The U.S. Department of Energy (DOE) will be responsible for stewardship activities, such as monitoring and maintenance, within those areas associated with a Comprehensive Environmental Response, Conservation and Liability Act (CERCLA) remedy, as appropriate. Refuge workers are assumed to be present on site for most of the year and engaged in refuge maintenance and ecological work activities. A Comprehensive Conservation Plan is under development by the U.S. Fish and Wildlife Service (USFWS) (anticipated completion December 2004), in consultation with the Stakeholders. Specific refuge activities will be determined by this plan.

Figure 1.1 CRA Process



An exposure pathway describes a specific environmental route by which an individual receptor could be exposed to contaminants present at or originating from a site. After the primary source(s) and release mechanisms are identified for the Site, the resulting secondary sources and secondary release mechanisms are identified and described. Subsequent sources and release mechanisms are identified until the exposure pathways for each contaminant are fully delineated. A complete exposure pathway includes five necessary elements: source; mechanism of release, transport medium, exposure point, and intake route. If any of these elements are missing, the pathway is incomplete.

Exposure pathways and exposure routes in the SCM have been categorized as significant (S), insignificant (I), or incomplete (IC) using best professional judgment in consultation with EPA, CDPHE, and USFWS. Significant and insignificant exposure pathways are complete exposure pathways. Significant exposure pathways contribute the major portion of risk or dose. An insignificant pathway is complete but will not contribute significantly to the total risk or dose. An incomplete exposure pathway is missing one or more of the five elements necessary for a complete exposure pathway. There will be no exposure and the pathway will not contribute any risk or dose. All significant exposure pathways will be quantitatively assessed at RFETS, while insignificant and incomplete exposure pathways will be qualitatively addressed.

The comprehensive human health SCM, including all potentially viable exposure scenarios and pathways, is presented on Figure 2.1. Receptors in the SCM are described in detail below. Exposure factors for each significant pathway are presented in Section 4.0.

2.1 Receptors

Two types of receptors are associated with the wildlife refuge land use: the wildlife refuge worker (WRW) and the wildlife refuge visitor (WRV). These scenarios are evaluated in the SCM and will be assessed in the CRA. The WRW is assumed to be exposed to outdoor contaminants for an average of one-half the workday. Current planning by the USFWS does not include year-round offices or an onsite visitor center. A seasonally staffed visitor contact station may be built on the western side of the Site (USFWS 2003). If an office/visitor center was built on Site, there could be exposures to indoor contaminants for an average of one-half the workday for the WRW. The WRV will have very limited exposures to indoor contaminants. Primary exposures will be to outdoor contaminants, as discussed below.

The offsite resident will not be assessed for the CRA because risks have been adequately assessed in the OU 3 Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Report (DOE 1996a). Risks to an offsite receptor due to air transport are assessed in the annual National Emission Standards for Hazardous Air Pollutants Report for Radionuclides and the Annual Dose Assessment Report. The onsite resident will not be assessed because it is not a reasonably anticipated land use.

Ecological receptors will be identified and assessed Sitewide. Key ecological receptors have been selected to adequately represent the local ecological community and quantify the range of potential impacts (Section 7.0).

2.2 Human Health Exposure Scenarios

The following exposure scenarios define the exposure pathways and assumptions for the WRW and WRV. Insignificant and incomplete exposure pathways are also defined and discussed.

2.2.1 Wildlife Refuge Worker Exposure Scenario

The WRW scenario follows that used for the radionuclide soil action levels (RSALs) development (EPA et al. 2002) (Section 4.1.2). The WRW will be assessed in an indoor office scenario for an average of 50 percent of each day during a standard workweek of five days per week. The remaining 50 percent of the time will be spent outdoors on the Site. This receptor will be exposed to residual contaminants in the IA, as well as all other onsite locations. The WRW will conduct fieldwork that will result in limited exposure to contaminated soil, subsoil, sediment, and surface water. RFCA Attachment 5, Figure 1 (DOE et al. 1996 [as modified]), shows an area in the center of the Site that may be subject to institutional controls. This area will be retained by DOE, but will be seamlessly joined with the wildlife refuge. Therefore, this area will be assessed using the WRW receptor.

Stewardship activities, including monitoring and maintenance, will occur on Site. It is assumed that exposures due to these activities will be less than for the WRW scenario. Therefore, the WRW scenario provides an upper bound for risks due to these activities, and a specific “stewardship receptor” will not be assessed in the CRA.

Complete Exposure Pathways

Potentially complete exposure pathways from which exposures are expected for the WRW include:

- Ingestion of and dermal exposures to surface soil, subsurface soil, sediments, and surface water;
- Inhalation of volatiles and particulates; and
- External exposure to beta and gamma radiation from radionuclides present in soil, subsurface soil, sediment, and building rubble.

Complete and Significant Exposure Pathways

The exposure pathways for the WRW that are expected to be both complete and have the possibility of contributing significant risk are:

- Inhalation of surface, sediment, and subsurface soil particulates;
- Ingestion of surface soil, subsurface soil, and sediments;
- Dermal exposure to surface and subsurface soil and sediments; and
- External irradiation exposure from surface soil, sediments, and subsurface soil.

16

Figure 2.1 Human Health Site Conceptual Model

Primary Source	Primary Release Mechanism	Affected Media	Secondary Release Mechanism	Affected Media	Pathway Number	Wildlife Refuge Worker Pathways	Wildlife Refuge Visitor Pathways
Soil Subsoil Sediment Building Rubble	Stormwater Runoff (S)	Surface Water Streams / Seeps	Direct Contact		S-1	Oral (I) Dermal (I)	Oral (I) Dermal (I)
			Biotic Uptake	Fish	S-2	Oral (IC)	Oral (IC)
			Ingestion	Deer/Grazing Animals	S-3	Oral (IC)	Oral (I)
	Infiltration Percolation (I)	UHSU Groundwater	Percolation	LHSU Groundwater	I-1	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
			Domestic Use		I-2	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
			Surface water		I-3	Oral (I) Dermal (I)	Oral (I) Dermal (I)
	Volatilization (V)	Groundwater Subsurface Soil Surface Water		Indoor Air Outdoor Air Outdoor Air	V-1 V-2 V-3	Inhalation (I) Inhalation (I) Inhalation (I)	Inhalation (IC) Inhalation (I) Inhalation (I)
	Resuspension (R)	Airborne Particulates		Indoor Air Outdoor Air	R-1 R-2	Inhalation (S) Inhalation (S)	Inhalation (IC) Inhalation (S)
			Deposition	Deer/Grazing Animals	R-3	Oral (IC)	Oral (I)
	Plant Uptake (P)	Surface Soil		Deer/Grazing Animals	P-1	Oral (IC)	Oral (I)
Key to Exposure Pathways: S - Significant I - Insignificant IC - Incomplete	Direct Contact (D)	Surface Soil (0 to 0.5 foot) ^a			D-1	Oral (S) Dermal (S ^b)	Oral (S) Dermal (S ^b)
		Subsurface Soil (0.5 to 8 feet)			D-2	Oral (S) Dermal (S ^b)	Oral (IC) Dermal (IC)
		Subsurface Soil (Below 8 feet)			D-3	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
		Sediment ^a			D-4	Oral (S) Dermal (S ^b)	Oral (S ^b) Dermal (S ^b)
		Building Rubble			D-5	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
	Radioactive Decay (E)	Surface Soil			E-1	External Irradiation (S)	External Irradiation (S)
		Subsurface Soil			E-2	External Irradiation (I)	External Irradiation (I)
		Sediment			E-3	External Irradiation (S)	External Irradiation (I)
		Building Rubble			E-4	External Irradiation (I)	External Irradiation (I)

a. Surface soil and sediments to a depth of 0.5 foot will be combined for the exposure assessment.

b. Dermal exposures will be assessed for organic COCs only.

Complete but Insignificant Pathways

Best professional judgment has been used to designate exposure pathways that are considered complete, but are not anticipated to contribute significantly to Site risks to the WRW. This is generally due to a variety of factors that lead to low intakes. The following pathways are considered insignificant:

- Ingestion of surface water;
- Dermal exposure to surface water;
- Inhalation of volatiles from groundwater;
- Inhalation of volatiles from surface soil and subsurface soil; and
- External irradiation exposure from subsurface soil and building rubble.

Incomplete Exposure Pathways

Best professional judgment has been used to designate exposure pathways that are considered incomplete. Incomplete pathways imply that exposures are not anticipated and consequently will not contribute to Site risks to the WRW. The following pathways are considered incomplete:

- Ingestion of fish or deer/grazing animals from the Site;
- Ingestion of groundwater;
- Ingestion of homegrown produce or animal tissue; and
- Ingestion of building rubble.

2.2.2 Wildlife Refuge Visitor Exposure Scenario

The WRV scenario is based on the open space scenario used in the RSAL Report (EPA et al. 2002). The WRV includes both a child and adult who visit the Site 100 days/year for 2.5 hours/day, for a total of 250 hours/year. The remaining time is spent off site. Outdoor recreational activities will primarily be on and near established hiking trails. Hunting may be allowed on a very limited basis, possibly by lottery. It is assumed that this receptor may be exposed to residual contaminants. It is also assumed that the WRV will not conduct activities resulting in significant exposure to subsurface soil, surface water, or sediments.

Complete Exposure Pathways

Potentially complete exposure pathways from which exposures are expected for the WRV include:

- Ingestion of and dermal exposures to surface soil, subsurface soil, sediments, and surface water;
- Ingestion of deer or grazing animals;

18

- Inhalation of volatiles and particulates; and
- External exposure to beta and gamma radiation from radionuclides present in soil, subsurface soil, sediment, and building rubble.

Complete and Significant Exposure Pathways

The exposure pathways for the WRV that are considered both complete and to have the possibility of contributing significant risk are:

- Inhalation of surface soil and sediment particulates;
- Ingestion of surface soil and sediment;
- Dermal exposure to surface soil and sediment; and
- External irradiation exposure from surface soil and sediment.

Complete but Insignificant Exposure Pathways

Best professional judgment has been used to designate exposure pathways that are considered complete, but are not anticipated to contribute significantly to Site risks to the WRV. This is generally due to a variety of factors that lead to low intakes. The following pathways are considered to be insignificant:

- Ingestion of surface water;
- Dermal exposure to surface water;
- Ingestion of deer or grazing animals;
- Inhalation of outdoor air volatiles from surface water and groundwater;
- Inhalation of outdoor air volatiles from surface and subsurface soil;
- Inhalation of indoor air on Site; and
- External irradiation exposure from subsurface soil and building rubble.

Incomplete Exposure Pathways

Best professional judgment has been used to designate exposure pathways that are considered incomplete. No exposures are anticipated and will not contribute to Site risks to the WRV. The following pathways are considered incomplete:

- Ingestion of groundwater; and
- Ingestion of building rubble.

3.0 DATA COLLECTION AND EVALUATION

Actions: Identify data needs and data sources, assemble data, and evaluate data quality and adequacy.

Data evaluation and aggregation will be performed on an EU and Area of Concern (AOC) basis for the HHRA. Methods are described below. The DQO process specifies project decisions and techniques necessary to generate quality data and make associated conclusions (EPA 2000b). The DQO process will be used to:

- Define stated objectives;
- Define appropriate data collection methods;
- Establish necessary data types;
- Conduct data aggregation; and
- Specify acceptable levels of data quantity and quality necessary to support the risk assessment process.

Nature and extent data that have been collected historically at RFETS, and also progressively during RI/FS investigations and accelerated actions, will be identified and assembled. Verification and Data Quality Assessment (DQA) procedures will be used to verify the quality of collected data. Data that are no longer relevant due to accelerated actions will be filtered out of the data set. COCs will be identified to support a comprehensive HHRA and ERA. Risks will be evaluated and quantified for receptors by exposure scenarios and pathways for established EUs and AOCs, and summarized accordingly.

Site data will be used to evaluate sources of contamination and determine contaminant distributions. Exposure parameters, such as inhalation and ingestion rate, exposure frequency, and exposure duration, have been determined for identified Site-specific receptors. Toxicity data will be collected to identify or derive dose limits to human and ecological receptors. Physical and chemical parameters for all viable COCs will also be collected, as necessary, to support a complete toxicity assessment, assessment of impacts to receptors, and determination of environmental fate and transport mechanisms. Radiological data for pertinent radionuclides, including plutonium-239, americium-241, uranium-235, and uranium-238 will be collected to determine recent dose conversion factors and radiological emission data. Ecological data will be collected from the ecological screening assessments for the BZ and IA, including receptor species, biological information, and Site habitat usage.

3.1 Human Health Risk Assessment Data Quality Objectives

The CRA employs the EPA DQO process to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate for the intended purpose (EPA 2000b). The DQO process consists of seven steps that specify project decisions, the data

quality required to support those decisions, specific data types needed, data collection requirements, and analytical techniques necessary to generate the specified data quality. During the first six steps of the DQO process, the planning team develops decision performance criteria (i.e., DQOs) for the data collection design. All decision rules need to be considered, as appropriate. The final step of the process involves developing the data collection design based on the DQOs.

3.1.1 Step 1: State the Problem

Human health risks from exposure to residual contaminants present in environmental media at RFETS must be quantified to determine whether end-state long-term land use is protective and within the range of acceptable risk. The nature and extent of COCs must be adequately determined to quantify human health risks at RFETS.

The problem is:

“The risks to all human receptors exposed to residual contaminants present in environmental media following accelerated actions must be quantified in a technically sound and defensible manner.”

3.1.2 Step 2: Identify the Decision

The primary decision:

“Are risks to human receptors at RFETS following exposure to residual contamination acceptable based on the reasonably anticipated future land use?”

Resolution of the following key secondary decisions will be required to ensure completion of the CRA:

- Has a methodology been developed to adequately assess human health risks?
- Has a methodology been developed to adequately identify COCs?
- Is the CRA SCM adequate to define all viable exposure scenarios, exposure pathways, and receptors based on the reasonably anticipated future land use?
- Have all EUs and AOCs been adequately defined and established?
- Have the nature and extent of inorganic, organic, and radionuclide analytes within EUs been identified with adequate confidence, based on evaluation of Site process knowledge and analytical data?
- Have adequate samples been collected within EUs and AOCs to perform the risk assessment?

3.1.3 Step 3: Identify the Inputs to the Decision

Available historical information, sampling data, and risk assessment requirements will be used to determine adequate sampling locations and densities for EUs and AOCs.

21

The CRA DQA methodology (Section 3.1.5) will be applied to all data used in the CRA. Data will be screened through the COC selection process as described in Section 4.4. All data will also be screened using professional judgment to ensure it meets risk assessment needs. All selected COCs will be used to calculate risks to receptors.

3.1.4 Step 4: Define Study Boundaries

Study boundaries are used to define the spatial and temporal boundaries for data collection in support of the decision to quantify risk to receptors. Environmental media analyte data will be assessed for surface soil and sediments to a depth of 6 inches, and for subsurface soil from 6 inches to 8 feet. Existing environmental media data will be used when possible and additional sampling will be conducted if determined to be necessary. Sufficient samples will be collected to statistically evaluate the data, identify COCs, and quantify risk to receptors. Exposure to building rubble and buried pipeline materials will not be assessed and, therefore, samples of these materials will not be collected for the CRA (Section 4.0). RFCA, Attachment 14 (DOE et al. 1996 [as modified]) describes sampling subsurface soil associated with the pipelines. These results will be used in the CRA.

EUs will be established using a tiered approach. Functional EUs for the WRW and WRV receptors have been established based on watersheds, known patterns of contamination, and expected activity patterns. Known Individual Hazardous Substance Sites (IHSSs), Potential Areas of Concern (PACs), and Under Building Contamination (UBC) Sites of special interest will be grouped into AOCs based on PRG screening (Section 4.2). Analyte data will be aggregated at both the EU and AOC levels to quantify risk to human receptors.

Statistical evaluation of environmental data will include standard descriptive calculations; precision, accuracy, representativeness, completeness, and comparability (PARCC) parameter analyses; distribution testing; population testing of Site data relative to background; nonparametric tests; and probabilistic resampling techniques, such as Bootstrapping and power calculations.

Data from environmental media will not be collected to support exposure pathways designated as insignificant.

3.1.5 Step 5: Identify the Data Adequacy Decision Rules

This section presents the decision rules to determine data adequacy for the CRA. The nature and extent of inorganics, metals, and radionuclides must be determined with sufficient certainty to permit adequate quantification of statistical analyses and quantification of risk to receptors. Data adequacy criteria must, therefore, be met or additional sampling and analysis will have to be performed.

The following decision rules will be used to determine whether analyte data are adequate to support statistical and risk-based calculations.

Data Sufficiency Assessment

The sample data collected for each COC in an EU or AOC will be used to determine an upper confidence limit at a 95 percent level (95UCL) of statistical confidence for the COC. The 95UCL will then be used as the EPC for the COC in the risk assessment. However, 95UCLs are only valid if sufficient numbers of sample data are available. While it is

possible to calculate a 95UCL with only two or three samples, its validity is questionable. Therefore, it is necessary to determine how many samples are required to calculate a 95UCL for each COC.

Sampling power will be evaluated to statistically determine whether sufficient samples were collected to adequately determine COCs and calculate 95UCLs within the EUs and AOCs to support risk assessment. The decision to be made is:

“Given the estimate of the mean analyte concentration, the observed variance, and the calculated 95UCL, is the number of samples collected adequate to identify an exceedance of PRGs for the WRW (at risk = 10^{-6} or hazard quotient [HQ] = 0.1) with an alpha error of 0.1 and a beta error of 0.2?”

All potential contaminants of concern (PCOCs) will be evaluated.

The CRA will use the nonparametric method as presented in the Multi-Agency Radiological Survey and Site Investigation Manual (MARSSIM) Report §5.5.2.3 (NRC 1997) for determining data sufficiency.

Estimates of the averages and variances will be derived as required to calculate the 95UCLs. Relative errors will be derived from the difference between the PRG and the mean and 95UCL. Relative errors derived from averages and 95UCLs will bound sampling errors due to inherent heterogeneity of analytes in environmental media to predict the number of samples required.

The results for all PCOCs detected in each EU and AOC will be summarized. The results of the data sufficiency calculations for each area will be evaluated collectively. At this point, other information on historical releases, Site usage, and process knowledge will also be reviewed. A decision will be made whether the data are sufficient or insufficient for the CRA. Results will be presented to the regulatory agencies for their concurrence.

PARCC Parameter Assessment

Data quality and adequacy will also be assessed using a standard PARCC parameter analysis (EPA 2000c) for all data in each environmental media as described below:

Precision

For nonradiological contaminants, if the relative percent difference (RPD) between the target and duplicate, at concentrations five times the reporting limit (RL), is less than 35 percent for solids and 20 percent for liquids, the overall precision of the contaminant concentration is adequate. Otherwise, the magnitude of the imprecision must be addressed in the CRA and/or additional samples may be required (EPA 2000b).

For radiological contaminants, if the duplicate error ratio (DER) is less than 1.96, the overall precision of the contaminant concentration is adequate. Otherwise, the magnitude of the imprecision must be addressed in the CRA and additional samples may be required (EPA 2000b).

Accuracy

If overall accuracy complies with EPA methodology SW-846 (EPA 1994b), as verified through formal verification and validation (V&V) (EPA 2000b) of the results, then results may be used in the CRA without qualification. Otherwise, the magnitude of the inaccuracy(s) must be addressed in the CRA and/or additional samples may be required.

Representativeness

Prerequisites to the decision criteria posed below include an adequate number of valid sample results, as stipulated in the Completeness section, and sample acquisition and analysis under an approved Quality Program.

- If sampling locations are spatially distributed such that contaminant randomness and bias considerations are addressed, based on the site-specific history, then sample results are representative. Otherwise, the results must be qualified and/or additional samples acquired.
- If samples were analyzed by EPA method SW-846 and results were documented accordingly, as quality records, the sample results are representative of contaminant concentrations. Otherwise, results (the CRA) must be qualified and/or additional samples acquired.

Completeness

Completeness may be determined using either of the following determinations: (1) comparison of actual samples (collected) with the planned number of samples, where the plan was an approved CERCLA-based SAP, or 2) determination of sample power through an appropriate statistical model, such as EPA QA/G-4 (EPA 2000b), QA/G-9 (EPA 2000c), or MARSSIM (NRC 1997).

1) Planned vs. Actual Number of Samples

- If the overall completeness of the data in the EU of interest is at least 95 percent (for a given contaminant), the data are adequate. Otherwise, the data (CRA) must be qualified and/or additional samples acquired.

2) Sample Power Calculations

- If enough samples were collected to attain 95 percent confidence in decisions (i.e., the contaminant concentration of interest is less than its associated RFCA action level [AL]) within the given EU, the number of samples is adequate. Otherwise, the data (CRA) must be qualified and/or additional samples acquired.

Comparability

If chemical and radiological results are comparable within the aggregated (CRA) data set based on defined matrices and standardized units of measure (e.g., picocuries per gram [pCi/g] and milligrams per kilogram [mg/kg]), the data are adequate for use in the CRA.

Otherwise, the results must be converted or normalized, the CRA qualified, and/or additional samples acquired (EPA 2000c).

3.1.6 Step 6: Specify Tolerable Limits on Decision Errors

Sources of uncertainties in the risk assessments will be identified, minimized, and documented in the CRA. This may include use of upper-bound numbers or ranges of values, as applicable, for various parameters considered, concentration term estimates, contaminant transport, data distribution assumptions, and EU use assumptions.

Where alpha and beta errors are applicable in statistical hypothesis testing, these errors will also be documented. Alpha error will not exceed 10 percent in sample power calculations. Likewise, beta error will not exceed 20 percent in sample power calculations. Relative errors will be determined based on the differences between the PRG for an analyte and the upper 95UCL or the estimate of the average analyte concentration (EPA 2002a).

3.1.7 Step 7: Optimize the Design

Based on the iterative nature of the DQO process, any decision that is not consistent with project goals will result in a reinitiation of the DQO process. If determination of the nature and extent of analytes is found to be inadequate, further sampling will be initiated. If sampling power is determined to be inadequate for any given scenario and set of analyte data, more samples will be collected and the sampling power will be recalculated.

4.0 EXPOSURE ASSESSMENT

Actions: Identify potential land use and exposed populations; develop the SCM, exposure factors for each pathway, and EUs for data aggregation; identify COCs; determine whether transport modeling is necessary; estimate COC EPCs; and quantify intake to receptors.

The CRA human health exposure assessment will quantitatively and qualitatively evaluate contact between human receptors and COCs. The exposure assessment will estimate the total dose or intake for a receptor in an EU or AOC for a particular land use and exposure scenario. The calculated dose is then combined with chemical-specific dose-response data to estimate risk (EPA 1992a). The exposure assessment methods for the HHRA are described in detail in the following sections.

4.1 Exposure Factors

This section presents the exposure factors for the HHRA.

4.1.1 Exposure Pathway Assessment

Exposure pathways, the course a contaminant takes from the source to a receptor, are shown in the SCM (Figure 2.1). In the model, exposure pathways are designated as incomplete (IC), complete and significant (S), or complete and insignificant (I) as defined previously.

Direct contact with surface soil, subsurface soil (less than 8 feet in depth), and sediments; the inhalation of airborne contaminants; and exposure to penetrating radiation are the primary exposure pathways of concern. Contact with subsurface soil is considered for the WRW, but is limited in both exposure frequency and exposure duration. Ingestion of and dermal contact with surface water, and volatilization of contaminants are considered insignificant pathways. Ingestion of animal tissue is incomplete for the WRW, but is considered insignificant for the WRV due to possible limited hunting activity. All other exposure pathways are considered incomplete and will not be addressed, including ingestion of groundwater and fish.

Inhalation Pathway

The inhalation pathway will be assessed for resuspension of airborne contaminants present in surface soil transported to human and ecological receptors. The receptors will be assessed for this exposure pathway using the contaminant concentration in the soil and the mass loading variable developed for the RSALs. The potential volatilization of contaminants from soil and shallow groundwater to receptor locations is considered an insignificant pathway. Volatilization into office space will be evaluated for WRW offices Sitewide, if determined to be a significant pathway.

Ingestion Pathway

The ingestion pathway will be assessed for direct ingestion of contaminants present in surface soil and sediments for the WRW and WRV receptors. Direct ingestion of surface water will not be assessed for the WRW and WRV receptors. Contamination and transport of groundwater in the upper hydrostratigraphic unit (UHSU) to surface water will also not be assessed. Ingestion of deep aquifer groundwater will not be assessed as a viable exposure pathway.

Runoff from contaminated soil to nearby surface water could result in direct ingestion of contaminated surface water by all receptors and contribute to possible contamination of aquatic species. However, direct ingestion of surface water and contaminated fish collected from the area are considered insignificant or incomplete pathways, respectively, and will not be assessed. Collection of meat from hunting activities and subsequent ingestion is also considered insignificant and will not be assessed.

Dermal Exposure

Dermal exposure due to contact with contaminated soil and sediments will be assessed for the WRW and WRV receptors. Dermal exposure to surface water will not be assessed for either receptor.

External Exposure

External exposure will be assessed for both receptors to determine impacts to human receptors resulting from exposure to external penetrating radiation emanating from radionuclides present in contaminated environmental media and associated contamination.

4.1.2 WRW Scenario Exposure Factors

The exposure factors for the WRW are presented in Table 4.1. Factors are taken from the RSALs Task 3 Report (EPA et al. 2002) when available. Dermal exposures were not

included in the RSALs. The sediment and subsurface pathways also were not assessed in the RSALs report.

Table 4.1 CRA Exposure Factors for the On-Site Wildlife Refuge Worker Receptor

Exposure Factor	Abbreviation	Units	Value	Source
Chemical concentration in medium	Cs	mg/kg/pCi/g	chemical-specific	
Adult body weight	BWa	kg	70	EPA 1991
Surface soil/sediment exposure frequency	EFwss	day/yr	250	EPA et al. 2002
Surface-subsurface soil/sediment exposure frequency	EFwsub	day/yr	20	DOE 2003
Exposure duration	EDw	yr	18.7	EPA et al. 2002
Exposure time	ETw	hr/day	8	EPA et al. 2002
Exposure time fraction, outdoor	Eto_w	--	0.5	EPA et al. 2002
Exposure time fraction, indoor	Eti_w	--	0.5	EPA et al. 2002
Averaging time - noncarcinogenic	ATnc	day	6826	Calculated
Averaging time - carcinogenic	ATc	day	25550	Calculated
Soil/sediment ingestion rate	IRwss	mg/day	100	EPA et al. 2002
Skin-soil adherence factor	AFw	mg/cm ² -event	0.12 ^a	EPA 2001a
Event frequency	EVw	events/day	1	EPA 2001a
Skin surface area (exposed)	SAw	cm ²	3300 ^b	EPA 2001a
Soil dermal absorption fraction	ABS	--	chemical-specific	EPA 2001a
Inhalation rate	IRaw	m ³ /hr	1.3	EPA et al. 2002
Dilution factor, indoor inhalation	DFi	--	0.7	EPA et al. 2002
Mass loading, (PM10) for inhalation	MLF	kg/m ³	6.7E-08 ^c	EPA et al. 2002
Area correction factor	ACF	--	0.9	EPA et al. 2002
Gamma shielding factor (1-Se) outdoor	GSFo	--	1	EPA et al. 2002
Gamma shielding factor (1-Se)	GSFi	--	0.4	EPA et al. 2002
Gamma exposure factor (annual) surface soil = (EFwss / 365 day/yr)	Te_A	--	0.7	Calculated
Gamma exposure factor (annual) subsurface soil = (EFwsub / 365 day/yr)	Te_As	--	0.05	Calculated
Gamma exposure factor (daily) outdoor = (ETw*Eto_w hr/day / 24 hr/day)	Te_Do	--	0.15	Calculated
Gamma exposure factor (daily) indoor = (8 hr/day / 24 hr/day)	Te_Di	--	0.15	Calculated
Conversion factor-1	CF1	kg/mg	0.000001	
Conversion factor -2	CF2	g/kg	1000	
Conversion factor-3	CF3	g/mg	0.001	

- The skin soil adherence factor is the geometric mean for farmers. This value is recommended by CDPHE for use in the WRW PRGs.
- The skin surface area value is the EPA default for commercial/industrial exposures and is the average of the 50th percentile for men and women >18 years old wearing a short-sleeved shirt, long pants, and shoes. The value was recommended by CDPHE for use in the WRW PRGs.
- The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

4.1.3 WRV Scenario Exposure Factors

Current plans for the wildlife refuge include public uses similar to open space usage previously developed for RFETS, with trails for wildlife observation, hiking, and biking (USFWS 2003). The exposure time and duration factors for the WRV receptor, presented in Table 4.2, are based on a survey conducted by Jefferson County of open space users (Jefferson County 1996). The values were first used in the open space PRG calculations for the Site and were adapted for the RSALs Report.

Table 4.2 CRA Exposure Factors for the Wildlife Refuge Visitor Receptor

Exposure Factor	Abbreviation	Units	Value	Source
Concentration in medium	Cs	mg/kg / pCi/g	chemical-specific	
Adult body weight	BWa	kg	70	EPA 1991
Child body weight	BWc	kg	15	EPA 1991
Exposure frequency	EFv	day/yr	100	EPA et al. 2002 ^a
Exposure duration-adult	EDav	yr	24	EPA 1991
Exposure duration-child	EDcv	yr	6	EPA 1991
Exposure duration-total	EDt	yr	30	EPA 1991
Exposure time	ETv	hr/day	2.5	EPA et al. 2002 ^b
Adult averaging time - noncarcinogenic	ATancv	day	8760	Calculated
Child averaging time - noncarcinogenic	ATencv	day	2190	Calculated
Averaging time - carcinogenic	ATc	day	25550	EPA 1991
Adult soil ingestion rate	SIRav	mg/day	50	EPA et al. 2002
Child soil ingestion rate	SIRcv	mg/day	100	EPA et al. 2002
Age-adjusted soil ingestion rate for non-radionuclides	SIRageav	mg-yr/kg-day	57	Calculated
Age-adjusted soil ingestion rate for radionuclides	SIRagav_r	mg/day	60	Calculated
Adult skin-soil adherence factor	AFav	mg/cm ² -event	0.07 ^c	EPA 2001a
Child skin-soil adherence factor	AFcv	mg/cm ² -event	0.2 ^d	EPA 2001a
Event frequency	EVv	events/day	1	EPA 2001a
Adult skin-surface area (exposed)	SAav	cm ²	5700 ^e	EPA 2001a
Child skin-surface area (exposed)	SACv	cm ²	2800 ^f	EPA 2001a
Age-averaged surface area/adherence factor	SFSagav	mg-yr/kg-event	361	EPA 2001a
Dermal absorption fraction	ABS	--	chemical-specific	EPA 2001a
Outdoor inhalation rate - adult	IRov	m ³ /hr	2.4	EPA et al. 2002
Outdoor inhalation rate - child	IRcov	m ³ /hr	1.6	EPA et al. 2002
Age-averaged inhalation factor (non-radionuclides)	IRagav	m ³ yr/kgday	3.7	EPA et al. 2002
Age-averaged inhalation rate (radionuclides)	Iragav_r	m ³ /hr	2.2	EPA et al. 2002
Mass loading, (PM10) for inhalation	MLF	kg/m ³	6.7 E-8 ^g	EPA et al. 2002
Area correction factor	ACF	--	0.9	EPA et al. 2002
Gamma shielding factor (1-Se) outdoor	GSFo	--	1	EPA et al. 2002

28

Gamma exposure factor (annual) = (EFv / 365 day/yr)	Te_Av	--	0.3	Calculated
Gamma exposure factor (daily) = (ETv hr/day / 24 hr/day)	Te_Dv	--	0.1	Calculated
Conversion factor 1	CF1	kg/mg	0.000001	
Conversion factor 2	CF2	g/kg	1000	
Conversion factor 3	CF3	g/mg	0.001	

- Value is the 95th percentile of visitation frequency for open space users (Jefferson County 1996).
- Value is the 50th percentile of time spent for open space users (Jefferson County 1996).
- The adult skin-soil adherence factor is the EPA residential default and the 50th percentile for gardeners. This is the value recommended by CDPHE for use in the WRW PRGs.
- The child skin-soil adherence factor is the EPA residential default and the 95th percentile for children playing in wet soil. This is the value recommended by CDPHE for use in the open space user PRGs.
- The adult skin-surface area value is the EPA default for residential exposures and the average of the 50th percentile for males and females >18 years old wearing short-sleeved shirts, shorts, and shoes. The value was recommended by CDPHE for use in the WRW PRGs.
- The child skin-surface area value is the EPA default for residential exposures and the average of the 50th percentile for males and females from <1 to <6 years old wearing short-sleeved shirts, shorts, and no shoes. The value was recommended by CDPHE for use in the WRW PRGs.
- The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

4.2 Functional EUs and AOCs

Sources of contamination will be determined using available Site data to assess the spatial and temporal distribution of all classes of contaminants. This information will be used to support the selection of COCs and AOCs. The AOCs will be identified and illustrated on Site maps; source terms will be defined, to the extent possible, with available information. Significant data gaps for contaminant sources and distributions will also be identified and resolved.

4.2.1 EU Development

Human health risks and health hazards will be assessed in three ways at RFETS:

- An onsite WRW will be assessed based on exposure to COCs selected for each EU.
- An onsite WRW will be assessed based on exposure to COCs selected for each AOC, as determined by the procedure discussed below.
- An onsite WRV will be assessed based on exposure to COCs selected for each EU. The same EUs will be used for the WRV as for the WRW assessment.

The EUs for the WRW and the WRV are illustrated on Figure 4.1. AOCs will be established to define those areas that represent distinct potential impacts to receptors from the perspective of source terms, observed COCs, nature and extent of contaminant transport, and spatial locations.

As stated above, sources of contamination will be determined using Site data to assess the spatial and temporal distribution of all classes of contaminants. This information will be used to support the selection of COCs. Primary areas of contamination will be identified and depicted on Site maps to define AOCs. Data sufficiency will be assessed.

4.2.2 Defining and Assessing EUs

Risk assessments evaluate the long-term threats to human health and the environment. An EU is the area over which long-term risks to the chosen receptors are assessed. The EU is an embodiment of the exposure scenario and its size varies with the land use and receptor activities. Recreational or open space EUs are generally large, depend on the recreational activities envisioned for the Site, and represent the area over which a receptor ranges during recreational activities. The activities of a WRW are even more extensive and varied, and the area over which the worker will be exposed during a career is quite large.

The EUs integrate the above factors and also:

- Consider Site contaminant release patterns and distinct areas of contamination;
- Aggregate data on a watershed basis;
- Support future land use planning;
- Facilitate assessment of risk in functional areas; and
- Comply with RFCA/CERCLA requirements.

The EUs represent long-term activity areas in which the WRW and WRV will be exposed to residual contamination. The importance and relationship of the above items to long-term risks are discussed below.

Contaminant Release Patterns

Contaminant release patterns and known sources were incorporated in the delineation of the EUs, as shown on Figures 4.2 and 4.3. The objective is to assess areas with similar types of contamination on a collective basis. For example:

- The IA EU has the most IHSSs, PACs, and UBC sites and was the area most affected by industrial activities at the Site.
- The Wind Blown Area EU includes surface soil affected by the 903 Pad release that are characterized by elevated plutonium and americium activities.
- The Upper Walnut Drainage EU includes the A- and B-Series ponds, which have elevated levels of radionuclides in sediments.
- The No Name Gulch Drainage EU encompasses the Present Landfill and downgradient areas.
- The Lower Walnut Drainage EU stream sediments are affected by surface water flows from the ponds and erosion from the Wind Blown Area.
- The Woman Drainage EU is affected by the 903 Pad, the Original Landfill, and other IHSSs and PACs.
- The remaining four EUs are not significantly affected by releases from the Site.

Watersheds

The EUs were designed on a watershed basis. This was done to account for similar long-term fate and transport processes for residual contaminants in soil and sediments. The major surface transport process for contaminants in surface soil is overland flow and transport of eroded soil in surface water. The EUs represent distinct areas affected by the potential transport of residual contamination from well-defined sources and activity areas for the WRW and WRV receptors based on similar landscapes and habitats.

Future Land Use Planning

The EUs are designed to support future land use planning by assessing risks for areas aggregated by similar geography, ecology, and expected usage. This will enable planners and managers to use the results of the CRA to determine areas of the Site to target for more intensive recreational development or other uses, such as ranger offices or a visitor center for the refuge.

Assessment of Functional Areas

The EUs are representative of expected activity areas for the WRW or WRV receptors. The areas of the EUs vary from 398 to 1,069 acres, as shown in Table 4.3. Time-weighted activity areas for refuge personnel calculated from survey data collected for the Rocky Mountain Arsenal (RMA) are in the same size range, according to Table 4.4. The areas were calculated using the estimated time spent in each area size class, using the following formula:

$$\text{Time-Weighted Area} = \sum_{i=1 \text{ to } 3} (t_i/t_t * A_i) \quad (\text{Equation 4-1})$$

where:

t_t = the total time spent in all area size classes by all workers

t_i = the time spent in the i^{th} area size class by all workers

A_i = the i^{th} area (midpoint or maximum of size range)

Table 4.3 Areas of the RFETS EUs

Name	Area (acres)
Industrial Area	428
Woman Drainage	977
South Buffer Zone Area	1,069
Wind Blown Area	720
Upper Walnut Drainage	403
Lower Walnut Drainage	398
No Name Gulch Drainage	425
Inter-Drainage	591
Rock Creek Drainage	765
West Area	471

Table 4.4 Time-Weighted Average Activity Areas for Wildlife Refuge Workers*

Receptors	Parameter	Small Areas	Medium areas	Large areas
		(0-10 acres)	(10-500 acres)	(500-6,000 acres)
	Midpoint size of area (acres)	5	255	3,250
	Max size of area (acres)	10	500	6,000
All workers	Midpoint time-weighted area (acres)	2	126	332
	Midpoint EU size (time-weighted) (acres)	460		
	Max time-weighted area (acres)	4	248	613
	Max EU size (time-weighted) (acres)	865		
Workers spending at least 50 percent of time outdoors	Midpoint time weighted area (acres)	1.9	132	319
	Midpoint EU size (time-weighted) (acres)	453		
	Max time weighted area (acres)	3.8	260	589
	Max EU size (time-weighted) (acres)	852		
Workers spending at least 30 percent time outdoors and on site 100 percent of time	Midpoint time-weighted area (acres)	2	133	425
	Midpoint EU size (time-weighted) (acres)	560		
	Max time weighted area (acres)	3	261	784
	Max EU size (time-weighted) (acres)	1,048		
All workers spending at least 30 percent of time outdoors	Midpoint time-weighted area (acres)	1.8	132	421
	Midpoint EU size (time-weighted) (acres)	555		
	Max time-weighted area (acres)	3.5	260	777
	Max EU size (time-weighted) (acres)	1,040		

* Calculated from original survey data from Table B.2-14 (RMA IEA/RC Appendix B, 8/93) (reported times at middle and higher activities, outdoors) and from Table B.2att2-1,2,3,4,5,& 6 (RMA IEA/RC Appendix B, 2/15/94) (reported times doing specific tasks). Survey was performed by Shell for the Army's Baseline Risk Assessment for the RMA. WRW from Malheur, OR (M), Minnesota Valley, MN (MV), and Crab Orchard, IL (CO) were included in the survey. Carl Spreng and Diane Niedzwiecki of CDPHE then exercised professional judgment to decide land area for each task.

The EUs are also indicative of different functional areas. Activities performed in the drainages will vary from those performed in the upland areas due to variation in topography, vegetation, and habitat. The combination of the assessment of risks in the EUs and AOCs, which represent areas of intensive activity, will result in a complete assessment of the potential range in risks from residual contamination at the Site.

Compliance with RFCA/CERCLA Requirements

Under CERCLA, it must be shown that risks for expected land uses at the Site fall within the acceptable range of 1×10^{-6} to 1×10^{-4} . The assessments for the EUs will present a comprehensive evaluation of long-term risks to the designated receptors across the Site. The coupling of these results with assessments of the targeted AOCs will provide estimates of residual risks from the Site following accelerated actions.

4.2.3 EUs for the Wildlife Refuge Worker

As discussed above, EUs for the WRW, shown on Figure 4.1, incorporate information on contaminant releases, and watershed and drainage features, and are based on anticipated activity patterns. These EUs form the basis for the assessment of risks to the anticipated major receptor in the CRA, recognize distinct areas of contamination, and support land use planning. The EU assessment will be augmented with the AOC analysis and assessments. Together, they will provide a complete assessment of risks to the WRW.

The assessments for the EUs represent the risks the worker will encounter in discharging his duties across the Site. The nature of the work involves movement over the entire Site. Therefore, relatively small EUs do not represent true estimates of long-term risks to the worker. However, due to the nature of the distribution of residual contamination across the Site, some areas represent a greater risk to the worker. The combination of the EU assessments with the AOC assessments addresses this concern. The EU assessments will provide a realistic evaluation of long-term risks at the Site, while the AOC assessments will provide risk information on a localized basis.

The risk assessment flow for each WRW EU is given below:

1. The areas of the EUs are set forth in this methodology.
2. All surface soil, sediment, and subsurface soil sampling locations to a depth of 8 feet will be assessed at each EU for the WRW scenario.
3. A DQA will be performed on the samples in each EU to ensure that the data within each are of sufficient quantity and quality to perform a risk assessment.
4. The COC selection process will be applied to surface soil, sediments, and subsurface soil to a depth of 8 feet.
5. Data from the COC selection process will be used to determine AOCs to be assessed (Section 4.2.5).
6. Data will be aggregated by EU and risks will be characterized.

4.2.4 EUs for the Wildlife Refuge Visitor

The refuge visitor is envisioned as participating in a variety of activities at the wildlife refuge. The visitor may be under the guidance and oversight of a WRW. Therefore, the same EUs will be applied to assess risks to the WRV as for the WRW. Due to the less intensive usage of the Site by the visitor, an assessment by AOC will not be performed.

The risk assessment flow for each WRV EU is given below:

1. The EUs are set forth in this methodology.
2. All surface soil and sediment sampling locations in each EU will be assessed for the WRV scenario.
3. Surface soil and sediments will be combined for the COC selection process.
4. A DQA will be performed on the samples in each EU to ensure that the data within each are of sufficient quantity and quality to perform a risk assessment.

5. Data will be aggregated by EU and risks will be characterized.

4.2.5 Defining and Assessing AOCs

The following section outlines how the AOCs will be developed for the onsite WRW. Developing AOCs in the following manner will focus efforts on those areas with the highest contamination while minimizing efforts in areas where risks are known to be low. This evaluation also examines the environmental samples available to support the AOC determination.

AOCs for the Wildlife Refuge Worker

The onsite WRW exposure scenario will be assessed across all areas at RFETS on an AOC basis. The AOC for the WRW will be smaller than the EUs because a WRW may be exposed across a smaller area. Therefore, COC concentrations will be averaged over a smaller area for this exposure scenario. The extent of an AOC for the WRW will be less than the EU and will be determined by the results of the PRG screen.

The CRA DQA and exposure assessment provide the information for deriving the AOCs. The DQA determines whether the data are of sufficient quantity and quality for use in the risk assessment. The PRG screen in the exposure assessment removes all contaminants from consideration that have such a low risk that they can be dropped from the risk assessment.

The areal extent of the AOC for the WRW will be defined using the following steps:

1. All surface soil and sediment sampling locations at RFETS will be compared with the onsite WRW PRGs for a risk = 10^{-6} and a hazard index (HI) = 0.1.
2. The AOC will be defined as the area surrounding the location(s) above the WRW PRG where organics are present above the detection limit and metals/radionuclides are found above background for each COC.
3. The remaining steps of the COC selection process will then be applied to the AOC. If COCs exist, a risk assessment will be performed.
4. A DQA will be performed on the samples in each AOC to ensure that the data within each AOC are of sufficient quantity and quality to perform a risk assessment.
5. Human health risks will be developed for all COCs within each AOC.

4.3 Data Aggregation for Risk Assessment

Sampling and modeling contaminant data for onsite environmental media that meet the DQO and DQA requirements will be used to estimate human health and ecological risks on an EU/AOC basis (Section 4.2). The types of data aggregation to be performed for the HHRA are outlined in Table 4.5. Data for surface soil, subsurface soil, and sediments will be aggregated on an EU and AOC basis to estimate exposure concentrations and intakes to perform the CRA.

Table 4.5 Data Aggregation for the CRA

Exposure Scenario	Media	Exposure Unit	Area of Concern
Wildlife Refuge Worker	Surface Soil and Sediment	Yes	Yes
Wildlife Refuge Worker	Subsurface Soil	Yes	Yes
Wildlife Refuge Visitor	Surface Soil and Sediment	Yes	No
Wildlife Refuge Visitor	Subsurface Soil	No	No

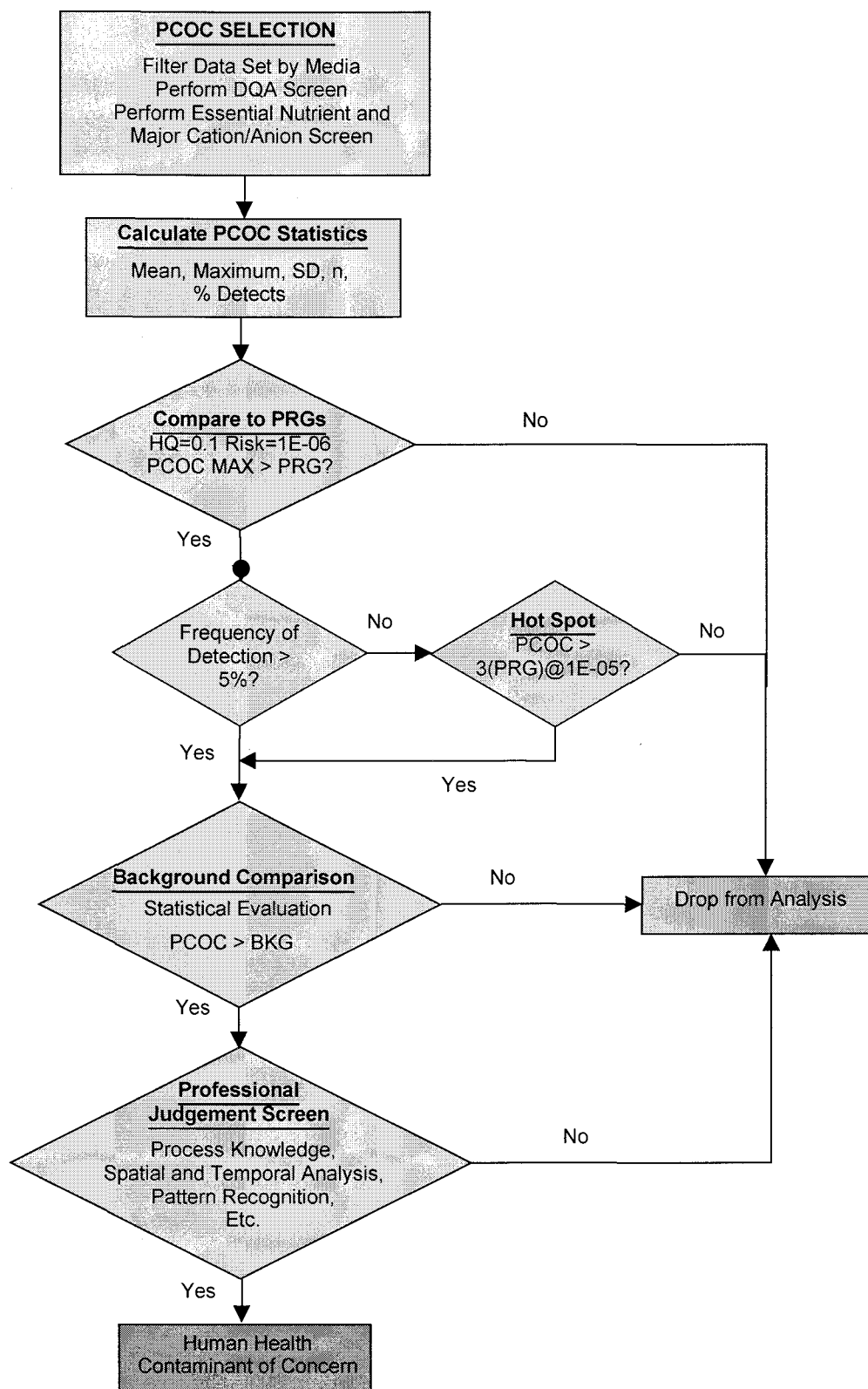
4.4 COC Identification and Selection

COCs will be selected for each media and identified on an EU and AOC basis. COCs will be determined for each individual EU and AOC because historical use of chemicals varied across the Site. The COC lists will be developed using the WRW PRGs or screening level PRGs. The WRW PRGs are documented in Appendix N of Appendix 3 of RFCA (DOE et al. 1996 [as modified]). Screening level PRGs have been developed specifically for the CRA for WRW exposure to subsurface soil, inhalation of volatiles in indoor air, and ingestion of surface water. These risk-based values will only be used for the CRA and will not be placed in RFCA. The screening level PRGs are documented in Appendix A. The WRW COCs will also be used for the WRV scenario.

4.4.1 Selection of EU and AOC COCs

The selection of EU and AOC COCs will follow the process outlined on Figure 4.4. The process will be repeated for each EU and AOC. Environmental media that will be included in the COC selection process are surface soil, sediment, and subsurface soil.

Figure 4.4 EU/AOC COC Selection Process



4.4.2 Data Quality Assessment

Data will be extracted and the DQA will be conducted to assess the quality of reported data as described in Section 3.1.5. Outliers will also be assessed using standard statistical testing and eliminated, if appropriate.

4.4.3 Data Aggregation

Data will then be aggregated on an EU basis by medium and analyte prior to initiation of the COC screening process. A value of one-half the reported value will be used for all U-qualified (nondetect) inorganic and organic data (EPA 1989). This does not apply to radionuclides, for which reported values will be used in all cases. A summary presentation of the data will include: chemical name; Chemical Abstract Service (CAS) number; chemical-specific, contract-required quantitation limit (CRQL); reported detection limit; number of samples; frequency of detection; minimum detected concentration; maximum detected concentration; arithmetic mean concentration; and standard deviation.

4.4.4 Elimination of Essential Nutrients/Major Cations and Anions

Intakes calculated based on maximum concentrations of essential nutrients in soil and sediment samples that have no toxicity value will be compared to daily reference intakes (DRIs) and upper limit daily nutrient intakes (ULs) in accordance with EPA guidance (1989). All essential nutrients that fall within the range of recommended or maximum daily intakes (NAS 2000a, 2002b) will be eliminated from further consideration in the CRA.

Nitrate, nitrite, ammonium, and fluoride have oral toxicological factors and will be assessed in the surface water screen. Nitrate will also be assessed in soil, due to its presence in groundwater. Sulfide, bicarbonate, bromide, carbonate, chloride, orthophosphate, and sulfate have no toxicological factors and will be eliminated from assessments in soil and sediments.

4.4.5 PRG Screen

All remaining PCOCs will be screened against the WRW PRGs presented in Appendix 3, Implementation Guidance Document, Appendix N, Preliminary Remediation Goals (DOE et al. 1996 [as modified]) and the screening level PRGs presented in Appendix A for the appropriate media using an HQ of 0.1 or risk of 1E-06. All PCOCs below the WRW PRG will be eliminated for the EU and any AOC within the EU. The PRG ratios for each PCOC will be presented in tables.

4.4.6 Detection Frequency Filter

Compounds detected at a frequency of 5 percent or greater will be carried through the COC selection process. Compounds detected at less than 5 percent frequency are not considered characteristic of Site contamination and the potential for exposure is low.

All analytes with less than 5 percent detection frequency will be compared to Site PRGs set to an HQ of 3 or risk of 3E-05 as a health-protective precaution as agreed upon and documented in the Industrial Area Sampling and Analysis Plan (IASAP) (DOE 2001). If the maximum detected value of an infrequently detected contaminant (less than 5 percent) exceeds the screening value, it will be carried on in the COC screening process.

4.4.7 Data Distribution Testing

Data distribution testing will be performed for all PCOCs retained following the PRG and frequency screens to aid in deciding the statistical test to use for comparison to background. Testing will be conducted following EPA guidance (EPA 2002b) and EPA QA/G-9 methods (EPA 2000c). The statistical tests to be used for determining data distributions are:

- Shapiro-Wilk Test (S-W) (test limited to $n > \text{or} = 30$ and $< \text{or} = 50$); and
- D'Agostino's Test (D'Agostino) ($n > 50$).

The test will be chosen based on sample size as recommended by EPA (2002b). Data sets with less than 30 samples will be considered to be lognormally distributed. If the chosen test identifies the distribution as normal, testing will stop and the data will be considered normally distributed. If not, the data will be log-transformed and tested again. The data will then be assigned a lognormal or nonparametric distribution, depending on the results. The assigned distribution will then be used to determine the appropriate test for the background comparison and estimate an appropriate upper 95UCL concentration.

4.4.8 Background Analysis

Following the determination of data distributions, inorganic and radionuclide PCOCs will be compared statistically to background data sets to determine whether the PCOCs are present at concentrations above background.

The background comparison is used to distinguish between contamination associated with Site activities and nonanthropogenic (naturally occurring) background conditions. The Geochemical Characterization of Background Surface Soils: Background Soils Characterization Program, Final Report (DOE 1995a) will be used for the surface soil background data. The Background Geochemical Characterization Report (DOE 1993a) will be used for the remaining media types. Background comparisons will be performed in accordance with current EPA guidance (2002b).

The statistical test chosen for a particular PCOC depends on the distributions of the PCOC and background data. Either parametric or nonparametric tests can be used, although neither work well with small data sets of less than 25 samples (EPA 2002b). Therefore, it is important that a combination of statistical testing be used to supplement the information from the statistical tests to compare the populations and other comparison methods including graphical, 95UCLs, outlier testing, and comparison of maximum values. The Wilcoxon (aka. Mann-Whitney) Rank Sum Test is useful when Site and background data have different assigned distributions or are both nonparametric (i.e., not normally or lognormally distributed). If Site and background data have the same normal or lognormal distributions, a Student's t-test can be used to compare PCOCs to background. Lognormal data are log-transformed prior to conducting a standard t-test. Evaluation of 95 percent confidence intervals for Site and background data can also be useful. Overlap of 95 percent confidence intervals indicates that the Site data are within the range of natural background.

If the concentrations for a particular PCOC are found to be significantly greater than background levels, the PCOC will be retained for further consideration. Following the background comparison, professional judgment will be applied and the final list of COCs will be determined.

4.4.9 Professional Judgment

Professional judgment is also used to include or exclude a PCOC from the final COC list. A PCOC that has been previously eliminated may be included because of a preponderance of historical data suggesting the chemical may have been released in significant quantities to the environment. Professional judgment can also be applied to develop a weight of evidence argument to exclude a PCOC based on data assessment, or spatial, temporal, or pattern-recognition concepts.

Data assessment includes an evaluation of laboratory and validation qualifiers. Spatial analysis requires that concentrations of each PCOC be plotted on a map; assessment of the plotted data should indicate their presence (or absence) or any trends in concentration, and assist in delimiting hot spots.

Temporal analysis is particularly relevant for groundwater data, where repeated sampling at a well offers the opportunity to evaluate changes in analyte concentrations over time. Time-series plots are used for this evaluation. Temporal analysis of data for sediments or other geologic materials is less useful and may not even be applicable.

Pattern recognition includes:

- Inter-element correlations;
- Similarities in geochemical behavior;
- Geochemical modeling to determine solubility controls on element concentrations;
- Correlations between elemental concentrations and certain parameters (total suspended solids [TSS], the negative logarithm of the hydrogen ion activity [pH], reduction-oxidation potential [Eh or pe, where $Eh = 0.059 \cdot pe$], clay content, organic content, cation-exchange capacity, and so forth); and
- Other recognizable patterns in elemental behavior.

Professional judgment will be applied on a case-by-case basis. All such judgment will be supported by a thorough analysis of the available evidence. Maps, figures, and references supporting the professional judgment will be presented.

4.4.10 Presentation of COCs

The COC selection process will be documented in tables, such as Table 4.6, that will summarize the data for each analyte chosen as a COC in each medium.

Table 4.6 Rationale for Selecting COCs

Analyte	PRG Ratio	Detection Frequency (%)	Hot Spot Ratio	Background Comparison	Professional Judgment	COC?

4.5 Pathway Significance Evaluations

Two pathways for the WRW are currently considered to have insignificant contributions to risk:

- Ingestion of contaminants transported from groundwater to surface water
- Inhalation of contaminants volatilizing from groundwater and soil

Evaluations will be completed to ensure that the designation as insignificant is appropriate. The evaluations are described below.

4.5.1 Groundwater-to-Surface Water Pathway

In the WRW scenario, the worker is potentially exposed to contaminants in surface water by ingestion while working. This pathway is currently considered insignificant. If contaminants known to be present in groundwater are transported to surface water in sufficient concentrations, this pathway could become a significant contributor to risk. The results of groundwater transport modeling can resolve this issue. Groundwater modeling for the Site is being done for a variety of purposes, one of which is to support the CRA. The objective of the transport modeling in support of the CRA is to simulate transport of contaminants from groundwater to surface water, and estimate future exposure concentrations in surface water for potential onsite receptors. A subsurface water transport model is under development to estimate surface water concentrations for the analytes selected by a screening procedure, using surface water PRGs developed for WRW (Appendix A) and ecological receptor (DOE et al. 1996 [as modified]) exposures to surface water.

The estimated concentrations after 30 years at select surface water locations will be subjected to the COC selection process in the CRA. Results will be used to estimate potential human health or ecological effects from surface water concentrations resulting from the transport of contaminants currently in groundwater. The transport model will be calibrated using available information on contaminant sources, current contaminant distributions, and

historical concentrations over time. DQOs for the modeling effort will accompany its documentation.

4.5.2 Groundwater/Subsurface Soil-to-Air Pathway

In the WRW scenario, the worker is potentially exposed to contaminants in groundwater that volatilize and are transported through the soil and released to the atmosphere, where they can be inhaled by the worker. Exposure to volatilized contaminants can occur indoors or outdoors. These pathways are both currently considered insignificant. The indoor route is considered a greater contributor to risk due to inhibited air exchange. If contaminants known to be present in groundwater are transported to the soil surface and then to the atmosphere in sufficient concentrations, the indoor pathway could become a significant contributor to risk. The WRW scenario currently includes an indoor component. An evaluation will be performed using the PRGs presented in Appendix A to determine whether indoor inhalation of volatilized subsurface contamination is a significant source of risk.

4.6 Exposure Point Concentrations

The EPC of a COC in a sampled medium is quantified using the 95UCL on the arithmetic mean (EPA 1989). The arithmetic mean is a statistically robust estimator, even when normality assumptions are not met (Gilbert 1987). The 95UCL on the mean is a conservative estimate of the average concentration to which receptors would be exposed over time in an exposure area. If the maximum detected COC value is below the 95UCL, the maximum concentration is used as the EPC. When data distributions are demonstrated to be lognormal, an arithmetic mean and 95UCL will be calculated using log-transformed data. When distributions are found to be neither normal nor lognormal, a nonparametric 95UCL will be calculated (EPA 2002a).

The one-sided confidence limit calculated using the Student's t-statistic will be used for normally distributed data with 30 or more samples (Gilbert 1987). EPA guidance (2002a) contains recommendations for several calculation methods for lognormally distributed data. Rather than use a battery of tests, the Chebychev inequality for calculation of the 95UCL has been chosen due to its versatility. The Chebychev method will be used for all lognormally distributed data and for data sets with less than 30 samples.

A Bootstrap nonparametric, probabilistic resampling methodology will be used to determine the 95UCL when observed data are not normally or lognormally distributed and have 30 or more samples. Bootstrap calculations of the 95UCL avoid difficulties associated with empirically determining the shape of the observed distribution because it has no distributional assumptions. This resampling technique provides estimates of the mean and variance for any distribution regardless of the specific shape and "performs substantially better, sometimes orders of magnitude better, in estimating the 95UCL of the mean from positively skewed data sets..." than other methods (EPA 1997). A normal Bootstrap program will be used to derive all mean and variance estimates. The Bootstrap method will be used to calculate EPC terms for estimating risk, as presented in EPA guidance (2002a). Estimates derived for the CRA will be developed using 2,000 or more resampling events. Use of 1,000 iterations has been demonstrated to be sufficient for estimating the mean and associated variance (DOE 2003).

EPCs will be estimated at human receptor locations for all pertinent environmental media, including surface and subsurface soil and sediment. The physical, chemical, and hydrogeologic characteristics of the Site must therefore be adequately studied and understood. Steady-state conditions will be assumed for EPCs based on direct environmental monitoring data. Effects of dilution, dispersion, source-term depletion, erosion, biodegradation, and sorption on quantification of the EPCs will be addressed in the uncertainty section of the CRA. EPCs will be estimated to realistically predict long-term averages and impacts to receptors.

EPCs for human receptors will be determined using measured environmental monitoring data. Subsurface soil concentrations will be used to estimate source terms for the possible transport of contaminants to groundwater and surface water locations and subsequent direct ingestion by human receptors.

4.6.1 Intake Calculations

Intake to receptors will be quantified for each selected COC, exposure pathway, and exposure scenario. Exposure factors reported in Section 4.1 will be used in the CRA. Intake in units of mg/kg per day will be calculated for all receptors exposed to ingestion, dermal, and inhalation pathways using the general formulas below. Radiological intake in units of picocuries (pCi) will be assessed using the standard EPA formulas. External radionuclide exposure is calculated in units of years per picocurie per gram (yr/pCi/g).

The equations for calculating intakes for the WRW and WRV are given in Tables 4.7 and 4.8. The abbreviations and specific values used for the exposure factors are defined in Tables 4.1 and 4.2.

Intakes are averaged over different time periods for carcinogenic and noncarcinogenic chemicals. For carcinogens, intakes are calculated by averaging the total cumulative dose during the exposure period over a lifetime, yielding a “lifetime average daily intake” (EPA 1989). For noncarcinogenic chemicals, intakes are calculated by averaging over the period of exposure to yield an average daily intake. Different averaging times are used for carcinogens and noncarcinogens because their effects occur by different mechanisms. The approach for carcinogens is based on the hypothesis that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime. The intake of a carcinogen is averaged over a 70-year lifetime regardless of exposure duration.

For calculation of radionuclide intakes, the exposure concentration is expressed in picocuries per liter (pCi/L), and the expression is not divided by body weight and averaging time. The resulting intake for radionuclides is expressed in pCi.

45

Table 4.7 Intake Equations for the WRW

Wildlife Refuge Worker
Surface Soil and Sediment Intake Equations
Intake Equation for WRW Ingestion
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IR_{wss} \times EF_{wss} \times ED_w \times CF_1)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Radionuclide Intake (pCi) = $Cs \times IR_{wss} \times EF_{wss} \times ED_w \times CF_3$
Intake Equation for WRW Dermal Contact
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times EF_{wss} \times ED_w \times EV_w \times SA_w \times AF_w \times ABS \times CF_1)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Intake Equation for WRW Outdoor Inhalation of Suspended Particulates
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IR_{aw} \times EF_{wss} \times ED_w \times ET_w \times ET_{o_w} \times MLF)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Radionuclide Intake (pCi) = $Cs \times IR_{aw} \times EF_{wss} \times ED_w \times ET_w \times ET_{o_w} \times MLF \times CF_2$
Intake Equation for WRW Indoor Inhalation of Suspended Particulates
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IR_{aw} \times EF_{wss} \times ED_w \times ET_w \times ET_{i_w} \times DFi \times MLF)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Radionuclide Intake (pCi) = $Cs \times IR_{aw} \times EF_{wss} \times ED_w \times ET_w \times ET_{i_w} \times DFi \times MLF \times CF_2$
Exposure Equation for WRW Outdoor External Radiation
Radionuclide Exposure (yr*pCi/g) = $Cs \times Te_A \times Te_Do \times ED_w \times ACF \times GS_{Fo}$
Exposure Equation for WRW Indoor External Radiation
Radionuclide Exposure (yr*pCi/g) = $Cs \times Te_A \times Te_Di \times ED_w \times ACF \times GS_{Fi}$
Subsurface Soil Intake Equations
Intake Equation for WRW Ingestion
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IR_{wss} \times EF_{wsub} \times ED_w \times CF_1)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Radionuclide Intake (pCi) = $Cs \times IR_{wss} \times EF_{wsub} \times ED_w \times CF_3$
Intake Equation for WRW Dermal Contact
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times EF_{wsub} \times ED_w \times EV_w \times SA_w \times AF_w \times ABS \times CF_1)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Intake Equation for WRW Outdoor Inhalation of Suspended Particulates
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IR_{aw} \times EF_{wsub} \times ED_w \times ET_w \times ET_{o_w} \times MLF)}{(BW_a \times [AT_c \text{ or } AT_{nc}]^a)}$
Radionuclide Intake (pCi) = $Cs \times IR_{aw} \times EF_{wsub} \times ED_w \times ET_w \times ET_{o_w} \times MLF \times CF_2$
Exposure Equation for WRW Outdoor External Radiation
Radionuclide Exposure (yr*pCi/g) = $Cs \times Te_As \times Te_Do \times ED_w \times ACF \times GS_{Fo}$

* Carcinogenic (ATc) or noncarcinogenic (ATnc) averaging times are used in equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated.

Table 4.8 Intake Equations for the WRV

Wildlife Refuge Visitor
Intake Equations for WRV Ingestion of Soil
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times SIRageav \times EFv \times CF1)}{[ATc \text{ or } ATnc]^a}$
Radionuclide Intake (pCi) = $Cs \times SIRagav_r \times EFv \times EDt \times CF3 \text{ units}$
Intake Equation for WRV Dermal Contact with Soil
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times EFv \times EVv \times SFSagav \times ABS \times CF1)}{[ATc \text{ or } ATnc]^a}$
Intake Equations for WRV Inhalation of Surface Soil
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRagav \times EFv \times MLF)}{[ATc \text{ or } ATnc]^a}$
Radionuclide Intake (pCi) = $Cs \times IRagav_r \times EFv \times (EDav + EDcv) \times ETv \times MLF \times CF2$
Exposure Equation for WRV External Radiation from Surface Soil
Radionuclide Intake (yr*pCi/g) = $Cs \times Te_Av \times Te_Dv \times ACF \times GSFo$

a. Carcinogenic (ATc) or noncarcinogenic (ATnc) averaging times are used in equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated.

5.0 HUMAN HEALTH TOXICITY ASSESSMENT

Action: Determine toxicity values and modes of action and endpoints for PCOCs.

Toxicity values are used to characterize risk, while toxicity profiles summarize toxicological information for radioactive and nonradioactive COCs. Toxicity information is summarized for two categories of potential effects: noncarcinogenic and carcinogenic. These two categories have slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens.

In general, toxicity profiles are obtained from EPA's Integrated Risk Information System (IRIS). IRIS contains only the toxicity values that have been verified and undergone extensive peer review by EPA's Reference Dose or Carcinogenic Risk Assessment Verification Endeavor (CRAVE) Work Groups. The IRIS database is updated monthly and supercedes all other sources of toxicity information.

If the necessary data are not available in IRIS, EPA's most recent issue of Health Effects Assessment Summary Tables (HEAST) will be used. It contains a comprehensive listing of provisional risk assessment information that has undergone review and has the concurrence of individual EPA Program Offices, but has not had the extensive review to be recognized agency-wide as consensus information. Values that have been withdrawn will not be used quantitatively unless the regulatory agency toxicologists (CDPHE and EPA) concur with their use for the CRA. Provisional values for toxicity factors are often available from the EPA's National Center for Environmental Assessment. These will be used with the concurrence of EPA and CDPHE toxicologists. EPA's HEAST for Radionuclides will be used as guidance for calculating radionuclide-specific cancer risk (EPA 2001b). Route-to-

route extrapolation of toxicity values will not be performed at RFETS except where oral criteria are used for dermal exposures. Consensus will be sought on all toxicity values used in the CRA.

Secondary sources of information will be used qualitatively in the HHRA. EPA toxicologists, both regional and national, may also serve as information sources. All information sources will be documented in the toxicity assessment. In general, the toxicity factors used for the Site PRGs will be used in the CRA, unless updates become available.

5.1 Identification of Toxicity Values for Carcinogenic Effects

Potential carcinogenic risks will be expressed as an estimated probability that an individual might develop cancer from lifetime exposure. This probability is based on projected intakes and chemical-specific dose-response data called cancer slope factors (CSFs). CSFs and the estimated daily intake of a compound, averaged over a lifetime, are used to estimate the incremental risk that an individual exposed to that compound may develop cancer. There are two classes of potential carcinogens: chemical carcinogens and radionuclides.

5.1.1 Chemical Carcinogens

Evidence of chemical carcinogenicity originates primarily from two sources: lifetime studies with laboratory animals and human (epidemiological) studies. Animal data from laboratory experiments represent the primary basis for the extrapolation for most chemical carcinogens. Experimental results are extrapolated across species (i.e., from laboratory animals to humans); from high-doses regions (i.e., levels to which laboratory animals are exposed) to low-doses regions (i.e., levels to which humans are likely to be exposed in the environment); and across routes of administration (e.g., inhalation versus ingestion).

EPA estimates human cancer risks associated with exposure to chemical carcinogens on administered-dose basis. It is assumed a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction. This mechanism for carcinogenesis means there is theoretically no level of exposure to a given chemical carcinogen that does not pose a small, but finite, probability of generating a carcinogenic response.

The CSFs are estimated using the linearized multistage model. The basis of this model is that multiple events may be needed to yield tumor induction (Crump et al. 1977) reflecting the biological variability in tumor frequencies observed in animal and human studies. The dose-response relationship predicted by this model at low doses is essentially linear. The CSFs calculated for nonradiological carcinogens using the multistage model represent the 95UCL of the probability of a carcinogenic response. Consequently, risk estimates based on these CSFs are conservative estimates representing upper-bound estimates of risk.

Uncertainties in the toxicity assessment for chemical carcinogens are dealt with by classifying each chemical into one of several groups, according to the EPA-defined, weight-of-evidence from epidemiological studies and animal studies. These groups are listed in Table 5.1.

Table 5.1 Carcinogen Groups

Weight-of-Evidence	Description
A	Human carcinogen (sufficient evidence of carcinogenicity in humans)
B	Probable human carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
C	Possible human carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
D	Not classifiable as to human carcinogenicity (inadequate or no evidence)
E	Evidence of noncarcinogenicity for humans (no evidence of carcinogenicity in adequate studies)

The oral and inhalation CSFs for the COCs will be compiled in a table. Table 5.2 presents the current CSFs used for calculation of the PRGs. These values will be updated as part of the RFCA annual review and incorporated into the CRA. A similar table of values will be included in the CRA.

5.1.2 Radionuclides

A series of federal guidance documents have been issued by EPA for the purpose of providing federal and state agencies with technical information to assist their implementation of radiation protection programs. The HEAST for Radionuclides (EPA 2001b) provides numerical factors, called “risk coefficients,” for estimating risks to health from exposure to radionuclides. This federal guidance will be used to calculate risk from radionuclides. It applies state-of-the-art methods and models that take into account age and gender dependence on intake, metabolism, dosimetry, radiogenic risk, and competing causes of death in estimating the risks to health from internal or external exposure to radionuclides.

A “morbidity risk coefficient” is provided for a given radionuclide and exposure mode. This coefficient is an estimate of the average total risk of experiencing a radiogenic cancer, regardless of whether the cancer is fatal. The risk coefficient associated with morbidity will be used to characterize human health risks. Current values used are shown in Table 5.2.

5.2 Identification of Toxicity Values for Noncarcinogenic Effects

Potential noncarcinogenic effects will be evaluated in the risk characterization by comparing daily intakes (calculated in the exposure assessment) with chronic reference doses (RfDs) developed by EPA. A chronic RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure that can be incurred during a lifetime, without an appreciable risk of a noncancer effect being incurred in human populations, including sensitive subgroups (EPA 1989). The RfD is based on the assumption that thresholds exist for noncarcinogenic toxic effects (e.g., liver or kidney damage). Adverse effects are not expected to occur with chronic daily intakes below the RfD value. Conversely, if chronic daily intakes exceed this threshold level, there is a potential that some adverse noncarcinogenic health effects might be observed in exposed individuals.

Tables 5.2 and 5.3 list the current values used for calculation of PRGs. These tables will be updated as necessary for the CRA.

5.3 Dermal Exposure to Chemicals

Because intake from dermal contact is estimated as an absorbed dose, EPA recommends using oral toxicity factors, adjusted if possible by a gastrointestinal absorption fraction, to evaluate toxic effects from dermal contact with potentially contaminated media (EPA 1989; 1992b; 2001a). The oral toxicity factor relates the toxic response to an administered intake dose of contaminant, which may be only partially absorbed by the body. When specific gastrointestinal absorption rates are not available, gastrointestinal absorption is assumed to be 100 percent and the unadjusted oral toxicity factor is used to assess the response to dermal absorption. Adjustments will be made to the oral toxicity factors in Tables 5.2 and 5.3 for assessing dermal exposures in the CRA. The values for the adjusted factors and the rationale will be presented in the CRA.

5.4 Identification of Radionuclide Dose Conversion Factors

Dose coefficients will be delineated according to federal guidance (EPA 1988a, 1993). Dose coefficients will be tabulated for the committed effective dose equivalent to tissues of the body per unit activity of inhaled or ingested radionuclides. The guidelines were derived to be consistent with current federal radiation protection guidance. The guidelines are intended to serve as the basis for setting upper bounds on the inhalation and ingestion of, and submersion in, radioactive materials in the workplace. The guidance also includes tables of exposure-to-dose conversion factors for general use in assessing average individual committed doses in any population adequately characterized by Reference Man (ICRP 1975).

The dose coefficients for external exposure to radionuclides distributed in air, water, and soil will be tabulated in accordance with Federal Guidance Reports Nos. 11 and 12 (EPA 1988a, 1993). The dose coefficients are based on dosimetric methodologies and include the results of calculations of the energy and angular distributions of the radiations incident upon the body and transport of these radiations within the body. Particular effort was devoted to expanding the information available for the assessment of the radiation dose from radionuclides distributed on or below the ground surface.

Dose coefficients for external exposure relate the doses to organs and tissues to the concentrations of radionuclides in environmental media. This is referred to as "external exposure," because the radiations arise outside the body. Intakes of radionuclides may also be by inhalation or ingestion, where the radiations are emitted inside the body. In either case, the dosimetric quantities of interest are the radiation dose received by the more radiosensitive organs and tissues of the body. Radiation of concern for external exposures are those sufficiently penetrating to traverse the overlying tissues of the body and deposit ionizing energy in radiosensitive organs and tissues. Penetrating radiations are limited to photons, including bremsstrahlung, and electrons. The radiation dose depends on the temporal and spatial distributions of the radionuclide to which a human is exposed. The mode considered for the CRA for external exposure is exposure to contamination on or in the ground.

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical ¹	CAS Number	Oral RfD (mg/kg-day)	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation RfD (mg/kg-day)	Inhalation Slope Factor (mg/kg-day) ⁻¹	Dermal ABS ² Fraction Absorbed
Acenaphthene	(V) 83-32-9	0.06	I			0.13
Acetone	(V) 67-64-1	0.1	I			
Aldrin	309-00-2	0.00003	I	17	17	0.1
Aluminum	7429-90-5	1	E	0.001	E	
Anthracene	(V) 120-12-7	0.3	I			0.13
Antimony	7440-36-0	0.0004	I			
Aroclor-1016	12674-11-2	0.00007	I	0.07	0.07	0.14
Aroclor-1221	11104-28-2		2		0.4	0.14
Aroclor-1232	11141-16-5		2		0.4	0.14
Aroclor-1242	53469-21-9		2		0.4	0.14
Aroclor-1248	12672-29-6		2		0.4	0.14
Aroclor-1254	11097-69-1	0.00002	I	2	0.4	0.14
Aroclor-1260	11096-82-5		2		0.4	0.14
Arsenic	7440-38-2	0.0003	I	1.5	15.05	0.03
Barium	7440-39-3	0.07	I			
Benzene	(V) 71-43-2	0.003	E	0.0001429	A	
alpha-BHC	319-84-6		6.3	0.055	0.029	0.04
beta-BHC	319-85-7		1.8	6.3	6.3	0.04
delta-BHC	319-86-8			1.8	1.8	0.04
gamma-BHC (Lindane)	58-89-9	0.0003	I	1.3		0.04
Benzo(a)anthracene	56-55-3		0.73	0.73		0.13
Benzo(a)pyrene	50-32-8		7.3	7.3	0.31	0.13
Benzo(b)fluoranthene	205-99-2		0.73	0.73		0.13
Benzo(k)fluoranthene	207-08-9		0.073	0.073		0.13
Benzoic Acid (at pH 7)	65-85-0	4	I			
Benzyl Alcohol	100-51-6	0.3	H			
Beryllium	7440-41-7	0.002	I	5.71E-06	I	I
bis(2-chloroethyl)ether	(V) 111-44-4		1.1	1.1	8.4	I
bis(2-chloroisopropyl)ether	(V) 39638-32-9	0.04	I	0.07	0.035	H

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical ¹	CAS Number	Oral RfD (mg/kg-day)	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation RfD (mg/kg-day)	Inhalation Slope Factor (mg/kg-day) ⁻¹	Dermal ABS ² Fraction Absorbed
bis(2-ethylhexyl)phthalate	117-81-7	0.02	I	I	0.014	E
Bromodichloromethane	(V) 75-27-4	0.02	I	I		
Bromoform	(V) 75-25-2	0.02	I	I	0.0039	I
Bromomethane (methyl bromide)	(V) 74-83-9	0.0014	I	0.0014286	I	
2-Butanone (methyl ethyl ketone)	(V) 78-93-3	0.6	I	0.2857143	I	
Butylbenzylphthalate	85-68-7	0.2	I			0.1
Cadmium (water)	7440-43-9	0.0005	I		6.3	I
Cadmium (food)	7440-43-9	0.001	I	0.000057	E	I
Carbon disulfide	(V) 75-15-0	0.1	I	0.2		
Carbon tetrachloride	(V) 56-23-5	0.0007	I	0.000571	E	I
alpha-Chlordane	5103-71-9	0.0005	I	I	0.0002	b
beta-Chlordane	5103-74-2	0.0005	I	I	0.0002	b
gamma-Chlordane	12789-03-6	0.0005	I	I	0.0002	b
4-Chloroaniline	106-47-8	0.004	I			0.1
Chlorobenzene	(V) 108-90-7	0.02	I	0.017	E	
Chloroethane (ethyl chloride)	(V) 75-00-3	0.4	E	2.8571429	I	
Chloroform	(V) 67-66-3	0.01	I	0.000086	E	I
Chloromethane (methyl chloride)	(V) 74-87-3			0.013	H	E
2-Chloronaphthalene	(V) 91-58-7	0.08	I			
2-Chlorophenol	(V) 95-57-8	0.005	I			
Chromium III	16065-83-1	1.5	I			
Chromium VI	18540-29-9	0.003	I	0.00003	H	H
Chrysene	218-01-9			0.0073	E	E
Cobalt	7440-48-4	0.02	E	0.0000057	E	0.13
Copper	7440-50-8	0.04	H			
Cyanide	57-12-5	0.02	I			
4,4-DDD	72-54-8			0.24	I	0.03
4,4-DDDE	72-55-9			0.34	I	0.03
4,4-DDT	50-29-3	0.0005	I	0.34	I	0.03

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical ¹	CAS Number	Oral RfD (mg/kg-day)	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation RfD (mg/kg-day)	Inhalation Slope Factor (mg/kg-day) ⁻¹	Dermal ABS ² Fraction Absorbed
Dibenz(a,h)anthracene	53-70-3		7.3	E	3.1	0.13
Dibenzofuran	132-64-9	0.004	E			0.1
Dibromochloromethane	124-48-1	0.02	I	I		0.1
Di-n-butylphthalate	84-74-2	0.1	I			0.1
1,2-Dichlorobenzene (o-)	95-50-1	0.09	I	0.04	H	
1,4-Dichlorobenzene (p-)	106-46-7	0.03	E	0.23	I	E
3,3-Dichlorobenzidine	91-94-1		0.45	I		0.1
1,1-Dichloroethane	75-34-3	0.1	H	0.1428571	A	
1,2-Dichloroethane	107-06-2	0.03	E	0.0014	E	I
1,1-Dichloroethene	75-35-4	0.009	I	0.6	0.175	I
1,2-Dichloroethene (total)	540-59-0	0.009	H			
2,4-Dichlorophenol (at pH 6.8)	120-83-2	0.003	I			
1,2-Dichloropropane	78-87-5		0.068	H	0.0011429	I
cis-1,3-Dichloropropene	10061-01-5	0.03	Ic	I	0.0057143	Ic
trans-1,3-Dichloropropene	10061-02-6	0.03	Ic	I	0.0057143	Ic
Dieldrin	60-57-1	0.00005	I	I	16	I
Diethylphthalate	84-66-2	0.8	I			0.1
2,4-Dimethylphenol	105-67-9	0.02	I			
Dimethylphthalate	131-11-3	10	W			0.1
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1	0.001	E			
2,4-Dinitrophenol	51-28-5	0.002	I			
2,4-Dinitrotoluene	121-14-2	0.002	I	0.68	I	
2,6-Dinitrotoluene	606-20-2	0.001	H	0.68	I	
Di-n-octylphthalate	117-84-0	0.02	H		0.014	E
Endosulfan I	959-98-8	0.006	I			0.1
Endosulfan II	33213-65-9	0.006	I			0.1
Endosulfan sulfate	1031-07-8	0.006	I			0.1
Endosulfan (technical)	115-29-7	0.006	I			0.1

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical ¹	CAS Number	Oral RfD (mg/kg-day)	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation RfD (mg/kg-day)	Inhalation Slope Factor (mg/kg-day) ⁻¹	Dermal ABS ² Fraction Absorbed
Endrin (technical)	72-20-8	0.0003	I			0.1
Ethylbenzene	(V) 100-41-4	0.1	I	0.2857143	I 0.00385	E
Fluoranthene	206-44-0	0.04	I			0.13
Fluorene	(V) 86-73-7	0.06	I			0.13
Heptachlor	76-44-8	0.0005	I 4.5	I	4.5	I 0.1
Heptachlor epoxide	1024-57-3	0.000013	I 9.1	I	9.1	I 0.1
Hexachlorobenzene	118-74-1	0.0008	I 1.6	I	1.6	I 0.1
Hexachlorobutadiene	87-68-3	0.0002	H 0.078	I	0.078	I 0.1
Hexachlorocyclopentadiene	77-47-4	0.006	I	0.000057	I	0.1
Hexachloroethane	67-72-1	0.001	I 0.014	I	0.014	I 0.1
Indeno(1,2,3-cd)pyrene	193-39-5		0.73	E		0.13
Iron	7439-89-6	0.3	E			
Isophorone	78-59-1	0.2	I 0.00095	I		0.1
Lead	7439-92-1					
Lithium	7439-93-2	0.02	E			
Magnesium	7439-95-4					
Manganese (Nonfood)	7439-96-5	0.02	I	1.429E-05	I	
Mercury (elemental)	7439-97-6			0.000086	I	
Methoxychlor	72-43-5	0.005	I			
Methylene chloride (dichloromethane)	(V) 75-09-2	0.06	I 0.0075	I 0.8571429	H 0.001645	I
2-Methylnaphthalene	(V) 91-57-6	0.02	E			
4-Methyl-2-pentanone (methyl isobutyl ketone)	(V) 108-10-1	0.08	H	0.0229	H	
2-Methylphenol (o-cresol)	95-48-7	0.05	I			0.1
4-Methylphenol (p-cresol)	106-44-5	0.005	H			0.1
Molybdenum	7439-98-7	0.005	I			
Naphthalene	(V) 91-20-3	0.02	I	0.0009	I	0.1
Nickel (soluble)	7440-02-0	0.02	I			
2-Nitroaniline	88-74-4			0.0000571	H	

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical ¹	CAS Number	Oral RfD (mg/kg-day)	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation RfD (mg/kg-day)	Inhalation Slope Factor (mg/kg-day) ⁻¹	Dermal ABS ² Fraction Absorbed
Nitrobenzene	(V) 98-95-3	0.0005	I	0.0004	A	
4-Nitrophenol	(V) 100-02-7	0.008	E			
n-Nitrosodiphenylamine	(V) 86-30-6		0.0049	I		
n-Nitrosodipropylamine	621-64-7		7	I		
Pentachlorophenol	87-86-5	0.03	I	0.12	I	0.25
Phenol	108-95-2	0.6	I			
Pyrene	129-00-0	0.03	I			0.1
Selenium	7782-49-2	0.005	I			
Silver	7440-22-4	0.005	I			
Strontium	7440-24-6	0.6	I			
Styrene	(V) 100-42-5	0.2	I	0.2857143	I	
1,1,2,2-Tetrachloroethane	(V) 79-34-5	0.06	E	0.2	I	
Tetrachloroethene	(V) 127-18-4	0.01	I	0.052	E	0.00203
Tin	7440-31-5	0.6	H			
Toluene	(V) 108-88-3	0.2	I	0.1142857	I	
Toxaphene	8001-35-2		1.1	I	1.1	0.1
1,2,4-Trichlorobenzene	(V) 120-82-1	0.01	I	0.0571	H	
1,1,1-Trichloroethane	(V) 71-55-6	0.28	E	0.63	E	
1,1,2-Trichloroethane	(V) 79-00-5	0.004	I	0.057	I	0.056
Trichloroethene	(V) 79-01-6	0.0003	E	0.4	E	0.4
2,4,5-Trichlorophenol	95-95-4	0.1	I			
2,4,6-Trichlorophenol	88-06-2		0.011	I	0.01	I
Uranium (soluble salts)	No CASN	0.003	I			
Vanadium	7440-62-2	0.007	H			
Vinyl acetate	108-05-4	1	H	0.0571429	I	
Vinyl chloride	(V) 75-01-4	0.003	I	0.72	I	0.0154
Xylene (total)	(V) 1330-20-7	2	I			
Zinc	7440-66-6	0.3	I			

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical ¹	CAS Number	Oral RfD (mg/kg-day)	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation RfD (mg/kg-day)	Inhalation Slope Factor (mg/kg-day) ⁻¹	Dermal ABS ² Fraction Absorbed
Nitrate	14797-55-8	1.6	I			
Nitrite	14797-65-0	0.1	I			
Ammonium (as Ammonia)	7664-41-7					
Fluoride (as fluorine)	7782-41-4	0.06	I	0.0286	I	

Notes:

1. Only those constituents in ALF are included.

2. Source: EPA 2001a.

I = IRIS (EPA 2002) H = HEAST (EPA 1997a) A = HEAST Alternate W = Withdrawn from IRIS or HEAST

E = EPA-NCEA provisional value

(V) = Chemicals listed are volatile.

a = Values given are for PCBs.

b = Values given are for chlordane (CAS No. 12789-03-6).

c = Values given are for 1,3-dichloropropene.

Table 5.3 Radiological Toxicity Constants*

Target Analyte List Chemical	CAS Number	Oral RfD (mg/kg-day)	Soil Ingestion Oral Slope Factor (Risk/pCi)	Water Ingestion Oral Slope Factor (Risk/pCi)	Food Ingestion Oral Slope Factor (Risk/pCi)	Inhalation Slope Factor (Risk/pCi)	External Slope Factor (Risk/yr/pCi/g)
Am-241	14596-10-2		2.17E-10	1.04E-10	1.34E-10	2.81E-08	2.76E-08
Pu-239	15117-48-3		2.77E-10	1.35E-10	1.74E-10	3.33E-08	2.00E-10
Pu-240	14119-33-6		2.77E-10	1.35E-10	1.74E-10	3.33E-08	6.98E-11
U-233	13968-55-3	3.00E-03	1.6E-10	7.18E-11	9.69E-11	1.16E-08	9.82E-10
U-234	13966-29-5	3.00E-03	1.58E-10	7.07E-11	9.55E-11	1.14E-08	2.52E-10
U-235	15117-96-1	3.00E-03	1.57E-10	6.96E-11	9.44E-11	1.01E-08	5.18E-07
U-235+D	15117-96-1(+D)	3.00E-03	1.63E-10	7.18E-11	9.76E-11	1.01E-08	5.43E-07
U-238	7440-61-1	3.00E-03	1.43E-10	6.4E-11	8.66E-11	9.32E-09	4.99E-11
U-238+D	7440-61-1(+D)	3.00E-03	2.1E-10	8.71E-11	1.21E-10	9.35E-09	1.14E-07

* Values are from HEAST for Radionuclides (EPA 2001b).

6.0 HUMAN HEALTH RISK CHARACTERIZATION PERFORMED ON AN EU AND AOC BASIS

Action: Characterize risks for the CRA in three ways:

1. An on-site WRW will be assessed based on exposure to COCs developed on the basis of the EUs, as discussed in Section 4.2.
2. An on-site WRW will be assessed based on exposure to COCs for AOCs determined by the methods discussed in Section 4.2.
3. An on-site WRV will be assessed based on exposure to COCs developed on the basis of the EUs.

To characterize risks, the chemical-specific intakes calculated in the exposure assessment are multiplied by the applicable chemical-specific, dose-response factors to compute estimates of the cancer risk for an individual over a lifetime of exposure, or the intakes are compared with RfDs (chronic, subchronic, or acute) for noncarcinogenic health effects. The nature, weight-of-evidence, and magnitude of uncertainty for the potential critical health effects are considered. The process of quantifying health risks includes the following:

- Calculating and characterizing carcinogenic effects for each COC, receptor, pathway, and exposure scenario;
- Calculating and characterizing noncarcinogenic effects for each COC, receptor, pathway, and exposure scenario;
- Calculating and characterizing radiation dose for each radionuclide COC, receptor, pathway, and exposure scenario; and
- Conducting qualitative (or quantitative, if necessary) uncertainty analysis.

6.1 Calculating and Characterizing Carcinogenic Effects

The following calculation will be used to determine carcinogenic effects by obtaining numeric estimates (i.e., unitless probability) of lifetime cancer risks:

$$Risk = Intake \times CSF \quad \text{(Equation 6-1)}$$

where:

Risk = potential lifetime excess cancer risk (unitless probability)

CSF = cancer slope factor ((mg/kg-day)⁻¹ or pCi⁻¹)

Intake = chronic daily lifetime intake (mg/kg-day or pCi) from equations in Table 4.7

CSFs will be used as provided in IRIS. Inhalation and oral ingestion CSFs are used with their respective inhalation and ingestion intakes to estimate potential carcinogenic health risks. The CSFs used are presented and discussed in the toxicity assessment (Section 5.1).

Cancer risks are summed separately across all potential chemical carcinogens and radionuclides considered in the risk assessment using the following equations:

$$Risk_{Tc} = \sum Risk_{ic} \quad \text{(Equation 6-2)}$$

$$Risk_{Tr} = \sum Risk_{ir} \quad \text{(Equation 6-3)}$$

where:

$Risk_{Tc}$ = total chemical cancer risk (unitless probability)

$Risk_{ic}$ = risk estimate for the i^{th} chemical contaminant (unitless probability)

$Risk_{Tr}$ = total radionuclide cancer risk (unitless probability)

$Risk_{ir}$ = risk estimate for the i^{th} radionuclide contaminant (unitless probability)

These equations are an approximation of the precise equation for combining risks to account for the probability of the same individual developing cancer as a consequence of exposure to two or more carcinogens. The difference between the precise equation and this approximation is negligible for total cancer risks less than 0.1 (10^{-1}). The risk summation assumes independence of action by the compounds (i.e., no synergistic or antagonistic actions). The limitations of this approach include conservative risk estimates due to the use of multiple upper-bound estimates of CSFs; increased uncertainty when adding potential carcinogenic risk across weight-of-evidence cancer classes (A through C); and uncertainty due to possible interactions among carcinogens.

A table of risks for each exposure scenario will be presented to show contaminant- and pathway-specific risk, with contaminants presented by rows and pathways presented by columns. Risks will be subtotaled across pathways for each contaminant.

A total carcinogenic risk will also be summed across weight-of-evidence classifications as an aid in the discussion of the uncertainty of the estimates. In accordance with EPA guidance, only one significant digit is retained when summarizing calculated risks (EPA 1989).

The CRA is an assessment of the human health and ecological risks from residual contamination. The pathways and contaminants driving the risk will be noted and accompanied by a discussion of any qualifying information.

In addition to presenting the incremental cancer risks due to contaminants at the Site, perspective may be provided by giving examples of typical background sources of risk, such as for arsenic or uranium. The text will note assumptions associated with the calculations, and discuss the importance of background risks associated with each exposure scenario. The CRA summary section will present risks for each scenario.

6.2 Calculating and Characterizing Noncarcinogenic Effects

Health risks associated with exposure to individual noncarcinogenic compounds are determined by calculating HQs and HIs. The noncarcinogenic HQ is the ratio of the intake or exposure level to the RfD, as follows:

$$HQ_i = \text{Intake}_i / \text{RfD}_i \quad (\text{Equation 6-4})$$

where:

HQ_i = noncarcinogenic HQ for i^{th} substance

Intake_i = intake for i^{th} substance (mg/kg-day) for appropriate exposure period

RfD_i = reference dose for i^{th} substance (mg/kg-day) for appropriate exposure duration

Inhalation and oral ingestion RfDs are used with their respective inhalation and ingestion intakes to estimate potential noncarcinogenic health effects. Intake and RfD are expressed in the same units and represent the same exposure period. The RfDs used are presented and discussed in the toxicity assessment of the CRA. COCs that have been determined to have subchronic (two-week to seven-year exposure) or acute (less than two-week exposure) effects in the toxicity assessment will be characterized using subchronic or acute RfDs, or other dose-response information, as available.

HI_s are the summed HQs for each chemical across an exposure pathway. An HI is calculated using the following equation:

$$HI_{pw} = \sum HQ_i \quad (\text{Equation 6-5})$$

where:

HI_{pw} = HI for an exposure pathway (unitless)

HQ_i = HQ for the i^{th} COC (unitless)

The HI_{pw} values are not statistical probabilities of a potential effect. If the HI_{pw} exceeds one, there is a concern for potential noncarcinogenic health effects. In general, the greater the HI above one, the greater the level of concern. However, the level of concern does not increase linearly as the HI approaches or exceeds one.

Noncarcinogenic effects will be presented in the CRA tables similar to those used in the presentation of carcinogenic risk. Each table will show contaminant- and pathway-specific effects with contaminants presented in rows, and pathways presented by columns. HI_{pw} s will be subtotaled across pathways to develop an HI for the exposure scenario (HI_{es}), if the same individuals would consistently be exposed to more than one pathway for each contaminant.

HQ_s approaching or exceeding one will be segregated and summed by mode of action or target organ to calculate the total HI by target organ (HI_{to}). A total HI_{to} will also be summed across all pathways and contaminants for a specific receptor scenario. Both of these procedures are subject to limitations. One significant digit is retained when summarizing the calculated indices.

The CRA will evaluate HQs and HIs that exceed one. Factors such as uncertainty inherent in the RfD(s), mode(s) of action, target organ(s), and severity of health effect(s) will be discussed. The pathways and contaminants driving the risk will be noted and discussed. A summary table presenting HI_{es} subtotalets for all scenarios will be created for presentation in the CRA risk summary section. This may be presented by placing the results for each scenario in rows, and providing information on HIs, dominant COCs, and dominant pathways in columns.

6.3 Dermal Assessment

As discussed in the toxicity assessment (Section 5.0), evaluation and assessment of risks for the dermal route are based on absorbed dose as opposed to the administered dose for other routes. The dermally absorbed dose (DAD) must be calculated separately and the toxicity factors adjusted according to estimated gastrointestinal absorption in critical studies. The cancer risk or HI is calculated using Equation 6.6:

$$\text{Dermal cancer risk} = DAD \times SFabs \quad (\text{Equation 6-6})$$

where:

DAD = dermally absorbed dose (mg/kg-day)
 $SFabs$ = absorbed CSF (mg/kg-d)⁻¹

The noncarcinogenic health hazard is calculated in a similar way:

$$\text{Dermal cancer risk} = DAD / RfDabs \quad (\text{Equation 6-7})$$

where:

DAD = dermally absorbed dose (mg/kg-day)
 $RfDabs$ = absorbed RfD (mg/kg-d)

6.4 Calculating and Characterizing Radiation Dose

The following calculation will be used to determine the radiation dose (NCRP 1985):

$$Dose = DCF \times Intake \quad (\text{Equation 6-8})$$

where:

DCF = dose conversion factor (millirems per picocurie [mrem/pCi] or millirems per picocurie per gram [mrem/pCi/g])
 $Intake$ = radionuclide intake or media concentration (pCi or pCi/g)

Inhalation and oral ingestion DCFs are used with their respective inhalation and ingestion intakes to estimate radiation dose. For external irradiation, external DCFs are used with their respective soil concentrations to estimate radiation dose. DCFs are calculated using mathematical extrapolation models based on human epidemiological studies.

Radiation dose is summed separately across all potential radionuclides considered in the dose assessment using the following equation:

$$Dose_T = \sum Dose_i \quad (\text{Equation 6-9})$$

where:

$Dose_T$ = total radiation dose, expressed in millirems (mrem)
 $Dose_i$ = radiation dose estimate for the ith radionuclide

A table of radiation doses for each exposure scenario will be created to show contaminant- and pathway-specific dose, with radionuclides presented by rows and pathways presented by columns. Reasonable exposure pathway combinations will be identified and the likelihood that the same individuals would consistently be exposed by more than one pathway will be evaluated. In most situations, a receptor could be exposed by several pathways in combination. For these situations, dose will be subtotaled across pathways for each radionuclide.

In addition to presenting the incremental radiation dose due to radionuclides at the Site, perspective may be provided by giving examples of typical background sources of dose from anthropogenic and terrestrial sources. Assumptions associated with the calculations will be noted and discussed. The CRA summary section will present doses for each exposure scenario and present a brief discussion of the uncertainty of the risk estimates.

6.5 Conducting an Uncertainty Analysis

The uncertainty analysis characterizes the various sources and their contributions to uncertainty in the CRA. These uncertainties are driven by uncertainty in the Site investigation data, likelihood of hypothetical exposure scenarios, transport modes used to estimate concentrations at receptor locations, receptor intake parameters, and toxicity values used to characterize risk. Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

The concept of uncertainty can be more fully defined by distinguishing between variability and knowledge uncertainty. Variable parameters are those that reflect heterogeneity in a well-characterized population, for which the distributions would not generally be narrowed through further measurement or study. Certain parameters reflect a lack of information about properties that are invariant and whose single, true value could be known exactly by the use of a perfect measuring device. Where appropriate, qualitative uncertainty analysis may distinguish between variability and uncertainty. This type of uncertainty analysis will identify each key source of uncertainty, present an estimate of the relative impact of the uncertainty on the CRA, and include any clarifying remarks.

There are four stages of analysis applied in the risk assessment process that can introduce uncertainties:

- Data collection and evaluation;
- Exposure assessment;
- Toxicity assessment; and
- Risk characterization.

The discussion of uncertainty is an important component of the risk assessment process. Point estimates of risk do not fully convey the range of information considered and used in developing the assessment (EPA 1992b). To provide information about the uncertainties associated with the reasonable maximum exposure (RME) estimate, uncertainties identified during the CRA process will be discussed qualitatively. In some cases, the effects on risks of the variability in some factors may be calculated to show potential risk ranges.

7.0 ECOLOGICAL RISK ASSESSMENT

Scope: Develop and document the methodology for the ERA portion of the CRA.

This section provides the methodology for the ERA in support of the CRA. The methodology uses existing RFETS ERA methodologies (DOE 1996b, 1996c) and more recent EPA guidance on performing ERAs at Superfund sites (EPA 1997, 1999, 2000b).

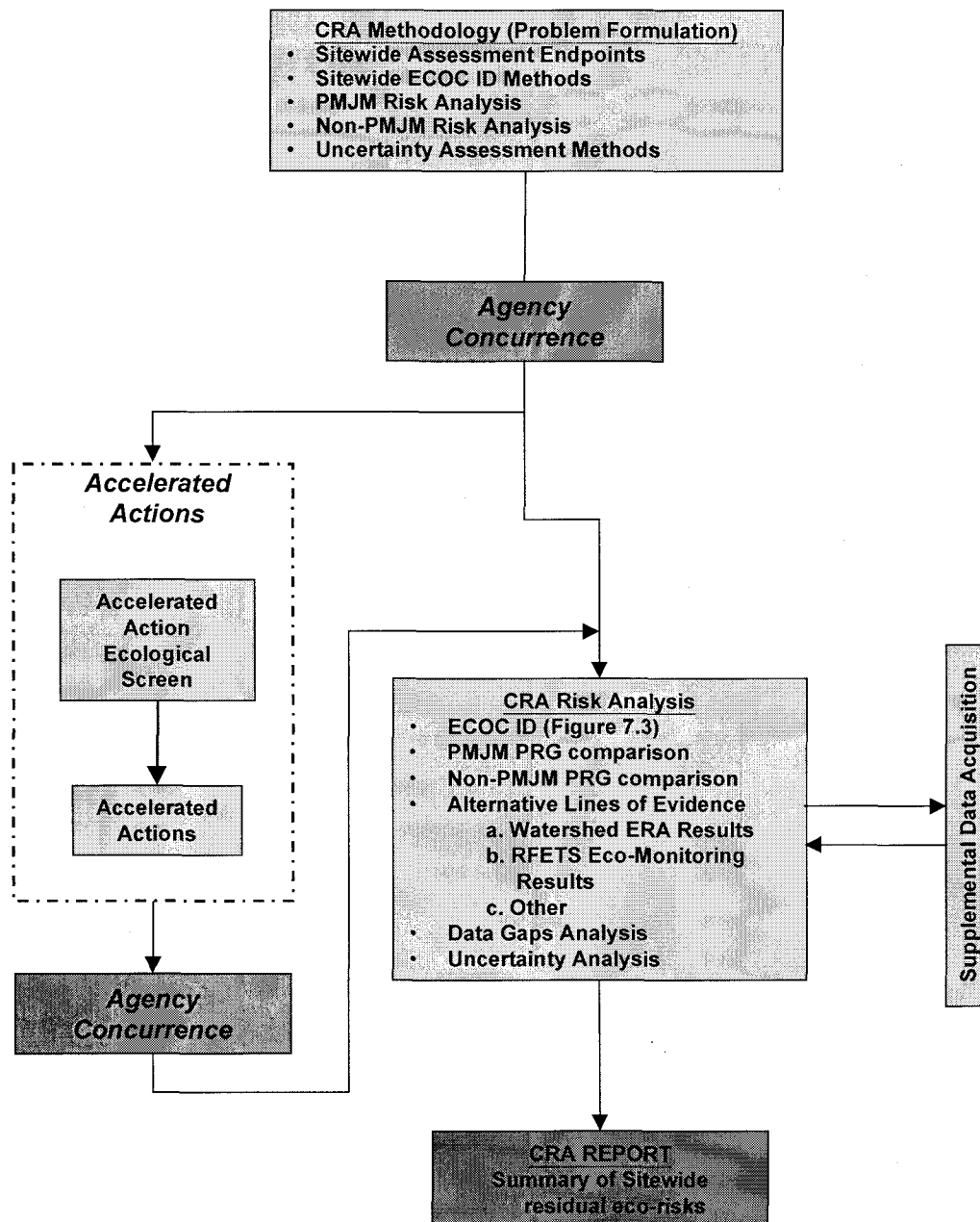
The existing RFETS methodologies were used to perform an ERA for the Woman and Walnut Creek watersheds in the BZ. The results were presented in the *Draft Final Phase I RFI/RI Report Appendix N, Woman Creek Priority Drainage Operable Unit No. 5* (DOE 1995b). Hereafter, this ERA will be referred to as the Watershed ERA.

An ERA has not been performed for areas within the IA. Buildings, parking lots, or other developed areas cover much of the IA. As a result, the IA does not currently represent a significant ecological resource. However, the reasonably anticipated land use for the IA will be a wildlife refuge and an ERA is needed to characterize the potential exposure and ecological risk due to residual contamination in soil or other media.

An overview of the ERA process is depicted on Figure 7.1. The ERA analysis is intended to document residual ecological risks after accelerated action. The analysis will include two main phases. Data on PCOCs in abiotic media from the Site will be compared to ecological PRGs that have been developed for abiotic media and a range of ecological receptor types. The analysis will be conducted using all Site data from previous investigations and confirmation sampling from accelerated actions. The PRG comparisons will be used to identify receptor of concern (ROC)/PCOC pairs for which PCOC concentrations exceed receptor-appropriate benchmarks, and to map the locations where the PRGs are exceeded.

Further analyses will be conducted for areas identified in the above analyses based on additional lines of evidence. Results of the Watershed ERA (DOE 1995b) will be reviewed in context of information that has been developed since the Watershed ERA, such as the mapping of Preble's meadow jumping mouse (PMJM) habitat. On the basis of this review, data or information gaps will be identified and addressed in the CRA.

Figure 7.1 Sequence of Activities for Ecological Risk Assessment



PRGs will be specific to the ROCs and the level of protectiveness needed. For ROCs that are not protected by state or federal statute (e.g., threatened or endangered species), PRGs will represent exposures equal to the lowest observed adverse effects levels (LOAELs). PRGs for PMJM will be more protective because it is a rare species with legal protection. PMJM PRGs will be based on no observed adverse effects levels (NOAELs). PRGs are being developed for the analytes included in RFCA Attachment 5, Table 3 (DOE et al. 1996, [as modified]).

Data used for the PRG comparison process will be from abiotic media (soil, surface water, and sediment). For accelerated action areas, data will be from confirmation sampling. In addition, the ERA may use the results of Sitewide surface water and groundwater transport modeling efforts to predict exposure of aquatic and terrestrial species at points of potential discharge, such as hillside seeps (terrestrial) and streams (terrestrial and aquatic).

The following sections describe the approach proposed for the CRA. The sections are organized as follows:

- Section 7.1 describes the use of the Watershed ERA analysis in the CRA.
- Section 7.2 describes the background information for the CRA including the SCM. This section also presents the DQO analysis for the CRA, and an overview of the PRG development process.
- Section 7.3 describes the Sitewide ecological contaminant of concern (ECOC) identification process that will be used to identify the chemicals for which additional risk analyses are needed.
- Section 7.4 describes the overall CRA risk analysis approach to be implemented after accelerated action results data are available.

7.1 Use of Watershed ERA in CRA

Purpose: The results of the previously completed Watershed ERA will be used to support the current assessment of ecological risks from residual contamination at the Site.

Results of the Watershed ERA will be an important line of evidence in the risk analysis process. The Watershed ERA represents a comprehensive exposure and risk calculation process conducted specifically for the RFI/RI process at RFETS. The results will be used on several levels. For example, PRG calculations include assumptions about the extent to which ECOCs are accumulated from abiotic media to biota in the food chain. The literature-based bioaccumulation factors (BAFs) used in developing the PRGs are typically conservative and will tend to overestimate the ECOC concentrations in forage and prey which, in turn, tend to overestimate risk. BAFs are notoriously site-specific and the assumptions used in the PRG calculations may not match the reality at the Site. The Watershed ERA contains data on ECOC concentrations in biota throughout the active areas of the Site. These data were used in exposure

and risk calculations, eliminating the need for use of BAFs. Therefore, results of the exposure analyses will be used to determine whether the PRGs are overestimating risk for the Site.

Data from the Watershed ERA, RFI/RI reports, or ecological monitoring studies may be used in a data gap analysis to help determine whether additional data are needed to assess risks in specific areas. This may be especially applicable to PMJM habitats along the creeks where soil and biota data were collected. The results of the Watershed ERA can be used to determine whether additional data are needed to fill spatial data gaps along the drainages. Results of ecological monitoring at the Site may be used to help determine whether there is properly functioning habitat in the AOCs.

7.2 CRA Background, Site Conceptual Model, and Data Quality Objectives

Actions: Specify information needed on physical setting, develop SCM of ecological receptors and exposure pathways to guide the ERA process, specify risk management goals and assessment endpoints, and develop DQOs to guide the ERA process.

7.2.1 Environmental Setting

The description of the environmental setting at RFETS will be presented in Section 2.0 of the RI/FS Report and will include the physical characteristics of the Site, such as topography, geology, and hydrology. The types and extent of plant and animal communities present on Site will be discussed in the ERA.

After accelerated actions, species diversity, abundance, and habitats may change significantly. Therefore, it will be important to determine the following:

- Present and future extent of wetlands habitat on site;
- Sensitive/protected plant species habitat (i.e., Ute Ladies'-Tresses) on site;
- Present and future PMJM habitat locations on site;
- Other protected or special status species sightings or habitats on Site (e.g., bald eagles and peregrine falcons); and
- Vegetation/habitat types to be introduced in the IA.

Much of the above information is available from ecological characterization and monitoring activities for the Site. Site physical characteristics are well described. Surface water and groundwater flow patterns and future site configuration have been discussed in various reports that address Sitewide water balance, actinide migration, and land configuration. Results of these studies will be used in conjunction with data on nature and extent of contamination, select assessment endpoints, and ECOC screening methodologies to complete the problem formulation phase of the ERA.

7.2.2 Site Conceptual Model

Development of the SCM is the first step in the problem formulation, or planning, phase of ERAs (EPA 1997). The purpose of the SCM is to help identify environmental stressors and the potential pathways by which ecological receptors may be exposed to them. This step allows investigators to identify the potentially complete pathways that will become the focus of the ERA.

An SCM for the Watershed ERA was described in the Sitewide Conceptual Model Technical Memorandum (SCMTM) (DOE 1996c). The SCMTM established the relationships among the key components of the RFETS ecosystem and included the following information:

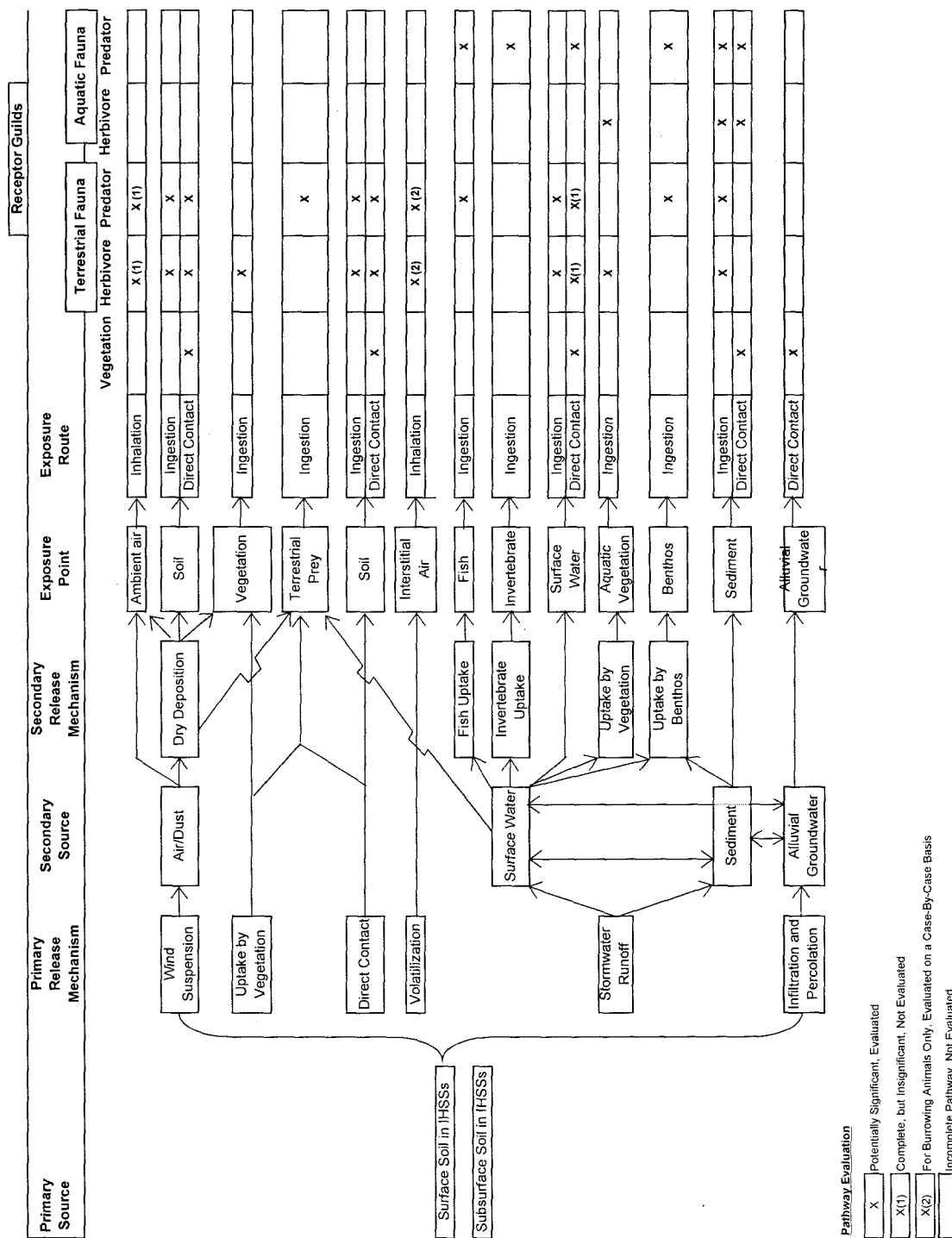
- Description of the environmental setting at RFETS, including the natural physical and biological systems and a brief description of the primary contaminant source areas or IHSSs;
- Description of the important contaminant fate and transport pathways in abiotic media;
- Description of the important exposure pathways, including primary exposure media, exposure points, receptor guilds, and exposure routes;
- Description of receptor guilds and identification of key species in each guild to be used in representative exposure estimates at RFETS;
- Species-specific exposure parameters to be used in estimating exposure to key receptors;
- Measurement endpoints for which data have been collected; and
- A summary of existing environmental data, data sources, and ongoing monitoring programs.

The SCM has been updated to reflect the most appropriate ecological receptors for the Site as a wildlife refuge (Figure 7.2). The purpose of the SCM is to help identify potential pathways by which ecological receptors may be exposed to PCOCs. The identified pathways become the focus of the ERA. The SCM will also be used to identify measurement endpoints for use in evaluation of assessment endpoints (Suter 1993).

Specifically, the ERA will provide the following:

- Description of the important contaminant fate and transport pathways in abiotic media;
- Description of the important exposure pathways, including primary exposure media, exposure points, receptor guilds, and exposure routes;
- Description of receptor guilds and identification of key species in each guild to be used in representative exposure estimates at RFETS;
- Species-specific exposure parameters to be used in estimating exposure to key receptors; and
- Measurement endpoints for which data have been collected.

Figure 7.2 Ecological Site Conceptual Model



7.2.3 Ecological Risk Management Goals and Assessment Endpoints

In order to focus ERAs, EPA (1997) recommends identifying overall Site management goals, and assessment endpoints on which the analysis of risk should focus. Assessment endpoints are the explicit description of the ecological values to be protected as a result of management actions at a Site. The overall risk management goal identified for use in developing the ERA for the CRA was:

- Site conditions after accelerated actions should not represent significant risk of adverse ecological effects due to exposure to Site-related residual contamination.

Significant adverse ecological effects means toxicity that results in reductions in survivorship or reproductive capability that threatens populations or communities at RFETS. For relatively rare and legally protected species with small populations, such as PMJM, significant adverse effects can occur even if individuals are affected. Therefore, the assessment for PMJM will address the potential for individual mice to be adversely affected by contact with PCOCs. For nonprotected species, the assessment will focus on population-level effects where some individuals may suffer adverse effects, but the effects are not ecologically significant because the overall Site population is not affected.

For PMJM, the overall risk management goal and assessment endpoints are:

- **Goal:** Prevent adverse effects on individual PMJM due to lethal, mutagenic, reproductive, systemic, or general toxic effects of contact with PCOCs from the Site.
- **Assessment Endpoint:** Survival, growth, and reproduction of individual PMJM at the Site.

For nonprotected ecological receptors, the risk management goal and assessment endpoints are:

- **Goal:** Prevent adverse effects on populations due to lethal, mutagenic, reproductive, systemic, or general toxic effects of contact with PCOCs from the Site.
- **Assessment Endpoint:** Survival, growth, and reproduction adequate to sustain populations at the Site.

The nonprotected receptors to be included as assessment endpoints for the Site are shown below. The receptors were identified based on ecological functional groups, then representative species were identified to focus the analysis.

Functional Group	Representative Species
Burrowing Small Mammal	Black-tailed Prairie Dog
Herbivorous or Omnivorous Small Mammal	Deer Mouse
Insectivorous Small Mammal	Deer Mouse
Herbivorous or Omnivorous Bird	Mourning Dove
Mammalian Predator	Coyote
Avian Predator	American Kestrel
Aquatic Life	General

7.2.4 Data Quality Objectives

As with the HHRA process, the approach to the ERA is presented in the format of DQOs (EPA 1997).

Step 1: State the Problem

Potentially toxic substances have been released at the Site. Ecological receptors could be exposed to the substances. To date, ecotoxicological risks have been characterized only for portions of the BZ in the Woman Creek and Walnut Creek watersheds (DOE 1995b).

The problem to be addressed by the ERA is:

“Site ecological conditions must be assessed after accelerated actions.”

Step 2: Identify the Decision

The ERA will characterize what is known about the exposures, and whether they have resulted, or could result, in significant adverse effects to ecological receptors. The overall Site management question to be addressed by the ERA is:

“Are residual long-term ecological risks from Site-specific contaminants acceptable for the long-term Site use and management goals?”

In order to address this general decision, additional decisions to be addressed include:

- Have the nature and extent of contaminants within accelerated action areas been identified with adequate confidence, based on Site history (process knowledge) and analytical data?
- Is further risk characterization necessary to make accelerated action decisions at the Site?

Step 3: Identify the Inputs to the Decision

Information needed to resolve the ERA decision statements is as follows.

- Existing data for areas under consideration;
- Results from a DQA screen (Section 3.1.5) applied for each type of environmental medium as prescribed in this methodology;
- Results from the preceding DQA screen compared to ecotoxicologically based screening level values;
- Ecological data that have become available since the completion of the previous ERAs (e.g., the Integrated Ecological Monitoring program); and
- Data and results from the previous ERAs conducted at RFETS.

Step 4: Define the Study Boundaries

Study boundaries are used to determine the areas from which data will be used, and identify where future sampling will occur. These study boundaries are listed below.

- Only data from characterization and confirmation sampling will be used. The assessment area will not extend beyond the current RFETS boundary.
- Soil will be assessed generally from the land surface to a maximum of 6 feet below ground surface. This depth was identified to protect burrowing mammals, and was used in developing PRGs.
- The ERA portion of the CRA will consider ECOCs in surface water. The contaminant load to surface water includes COC transport from surface soil, unsaturated and saturated zone soil, and sediments. The results of modeling the transport of groundwater to surface water will be compared to PRGs for aquatic life.

Step 5: Develop a Decision Rule

In addition to the decision rules cited for data adequacy in Section 3.0, decision rules that describe how the data will be evaluated for the ERA are listed below.

- If maximum concentrations Sitewide are greater than the NOAEL PRGs, then further evaluation is needed.
- If the maximum is greater than the PMJM NOAEL PRG and located in PMJM habitat, then the analyte is a PMJM ECOC.
- If the maximum is greater than the non-PMJM NOAEL PRG, the detection frequency is greater than 5 percent or the analyte presents a specific risk based on best professional judgment, and it is above background (inorganics and radionuclides), and the 95UCL is greater than the LOAEL PRG or the maximum is three times the LOAEL PRG for the ROC, the analyte is a non-PMJM ECOC.
- Non-PMJM receptors: If the ECOC for a non-PMJM ROC in the appropriate habitat, Sitewide, has a detection frequency greater than 5 percent or the ECOC presents a specific risk based on best professional judgment, and the 95UCL exceeds the LOAEL PRG or the maximum in the patch is three times the LOAEL PRG, then locations will be mapped and risks will be assessed.
- PMJM receptor: If the maximum concentration of an ECOC in a PMJM habitat patch exceeds the NOAEL PRG, or is three times the NOAEL PRG, Thiessen polygon mapping will be performed, and habitat patches for further risk analysis will be recommended. Decisions on habitat patches for further assessment will be made in consultation with the regulatory agencies.

Step 6: Specify Tolerable Limits on Decision Errors

Several sources potentially contribute uncertainty to the CRA. Best professional judgment and input from the regulatory agencies is needed for decisions regarding data gaps and risk management actions. EPCs for nonprotected species are often represented by the 95UCL limit of the mean for a data population. As a screening step for nonprotected species, this metric is compared to a specific PRG. Although not a formal hypothesis test, the implied Type 1 error rate (i.e., alpha) for this comparison is 5 percent, because use of the 95UCL

implies that the mean exposure is not expected to exceed the metric with more than 5 percent frequency.

Step 7: Optimize the Design

Based on the iterative nature of the DQO process, any decision that is not consistent with project goals will result in a reinitiation of the DQO process. If determination of the nature and extent of analytes is found to be inadequate, further sampling will be initiated. If sampling power is determined to be inadequate for any given scenario and set of analyte data, more samples will be collected and the sampling power will be recalculated.

7.2.5 Data Types and Adequacy

The SCM suggests that ecological receptors may be exposed to PCOCs in abiotic and biological media. Site data on PCOC concentrations in soil, surface water, and sediment will be evaluated to support the CRA. Biological tissue analysis results will not be used in the initial phase of the IA and CRA assessments. However, potential uptake of PCOCs into prey and forage species will be considered in development of the PRGs.

The IA and BZ SAPs (DOE 2001, 2002c) identify laboratory analytical methods to provide data with adequately low method detection limits (MDLs) and practical quantitation limits (PQLs) to allow meaningful comparison to ecological screening levels in abiotic media. PCOC concentrations in soil and sediment will be expressed as “total recoverable” (e.g., sample prepared for analysis by EPA Method 3050 or equivalent). PCOC concentrations in surface water will be appropriately compared to water quality standards for protection of aquatic life. Surface water data used to assess risks to wildlife drinking the surface water will be based on “total recoverable” (i.e., unfiltered) analyses.

In addition to the comparison of PRGs directly to analytical data, models may be used to estimate PCOC concentration in stormwater runoff from potentially contaminated soil and groundwater that may surface at seeps or in streams. Both sources of water could contact aquatic biota or wildlife.

Adhering to the specifications of the DQOs as outlined above will ensure the adequacy of data for use in the ERA. In addition, the DQA will help ensure that the quality of data is consistent with RFETS standards.

7.2.6 Ecological PRGs

As noted above, the CRA will be based on an assessment procedure similar to that adopted for assessment of human health risk in the accelerated action process. PRGs for wildlife will be developed based primarily on potential ingestion of ECOCs in abiotic media, forage, and prey; and the transfer of ECOCs among these exposure points. The specific methodology for developing PRGs will be presented under separate cover for regulatory agency review. The following is an overview of the processes intended for each of the environmental media.

Soil

EPA’s Ecological Soil Screening Levels (EcoSSLs) (EPA 2000a) process was used as a general guidance for developing the PRGs. Acquisition of primary literature, followed by

extensive review and scoring of the documents was not done. Instead, extensive use was made of existing databases and compilations of ecotoxicity information, especially those from other DOE facilities, such as Oak Ridge National Laboratory (ORNL) and Los Alamos National Laboratories.

Both NOAEL- and LOAEL-based PRGs will be developed for small mammals, ground-feeding birds, terrestrial invertebrates, and avian predators. The complete PRG development process is included in Appendix N of Appendix 3 of RFCA (DOE et al. 1996 [as modified]). PRGs will be developed for a list of Sitewide PCOCs listed in Attachment 5, Table 3 of RFCA (DOE et al. 1996 [as modified]).

Sediments

For sediments, sediment quality values (SQVs) have been developed for many chemicals and are available from several sources. SQVs are generally expressed as concentration terms and, therefore, require no calculations or assumptions. However, the assumptions underlying the development of SQVs will be evaluated to determine consistency with uses at RFETS.

Surface Water

For surface water, ecotoxicologically based water quality criteria are available from several sources. Only criteria appropriate for selected on-Site receptors will be used. PRGs will be taken from State of Colorado water quality standards, federal Ambient Water Quality Criteria, and other databases such as that from ORNL.

Radionuclides

Soil benchmarks for radionuclides were developed for RFETS during the Watershed ERA (Higley and Kuperman 1994). Since then, DOE's Biological Dose Assessment Committee has developed additional procedures for assessing exposure and risk to terrestrial and aquatic biota (DOE 2002b). These additional processes will be used to verify protectiveness of the earlier soil benchmarks, and evaluate protectiveness of available surface water criteria.

7.3 Sitewide ECOC Identification Process

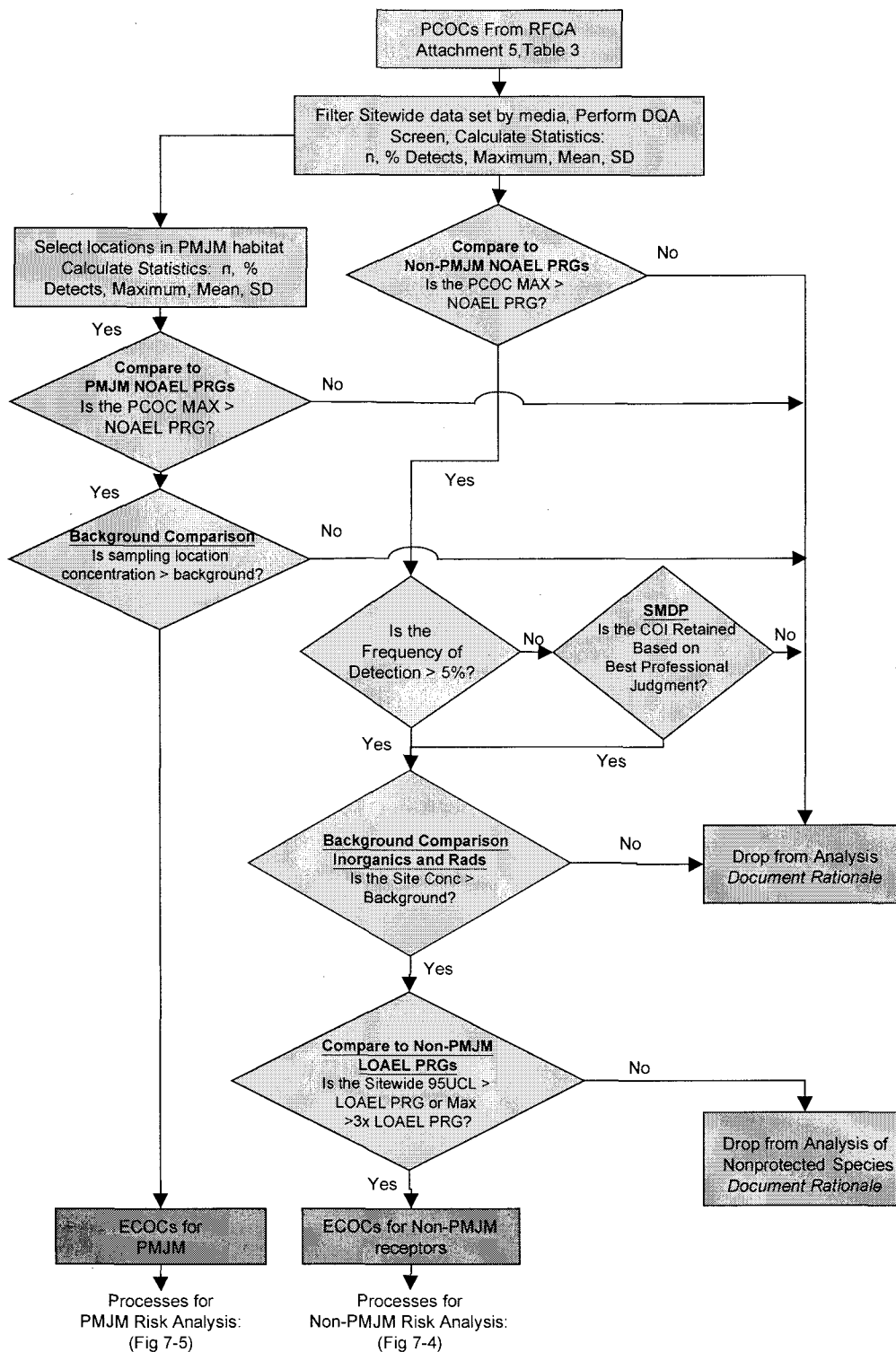
Action: Identify ECOCs for the ERA.

A comprehensive list of Sitewide ECOCs will be developed for the CRA based on data representing conditions after accelerated actions. PCOCs identified in RFCA Attachment 5, Table 3 (DOE et al. 1996 [as modified]) will form the starting point for the ECOC identification process shown on Figure 7.3.

The entire Sitewide database will be queried, filtered by media, and subjected to a DQA screen (Section 3.1.5) to identify which data meet the needs of the DQOs discussed in the previous section. Following the DQA screen, two data sets will be created. One will include

all Sitewide data; the other will include only sampling locations in PMJM habitat. For each data set, "U-" qualified nondetects will have one-half the reported result concentration substituted; basic descriptive statistics will then be calculated, such as number of samples, percent detections, maximum detections, mean detection, standard deviation, variance, and so forth.

Figure 7.3 Sitewide ECOC Screening Process



Soil data in each data set will be compared to NOAEL-based PRGs. If the maximum detected concentration of the PCOC does not exceed the NOAEL-based PRG, the PCOC will be dropped from further analysis in the CRA and the rationale for removing it from further analysis will be recorded and presented in the CRA Report. If the maximum detected PCOC concentration in the PMJM habitat data set exceeds the NOAEL-based PRG, it will be retained as an ECOC for the PMJM.

PCOCs that have detected concentrations greater than the NOAEL-based PRG in the Sitewide data set will undergo further analyses to determine their status as ECOCs. If the PCOC was detected in less than 5 percent of the samples, the PCOC will be evaluated using best professional judgment as to its potential to cause risk to wildlife receptors at the Site. This decision, or scientific management decision point (SMDP), will be made in cooperation with regulatory agency personnel. The determination will consider process knowledge, and spatial and temporal factors, as well as the physical and chemical properties of the PCOC as they pertain to the potential for risk to the wildlife receptors at the Site. If it is determined that no potential risk is expected, the PCOC will be dropped from further analysis and the rationale for the decision will be documented in the CRA Report. The radionuclide and metal PCOCs passing the 5 percent screen will then be statistically compared to background concentrations, as appropriate, using the methods discussed in Section 4.4.8.

For those PCOCs that remain, LOAEL-based PRGs will be compared with the Sitewide 95UCL concentrations. As an additional screening step, the Sitewide maximum detected concentrations of each remaining PCOC will be compared to three times the LOAEL-based PRGs. Any PCOC with a 95UCL concentration below the PRG or a maximum concentration below three times the PRG will be dropped from further analysis in the CRA for non-PMJM habitat. Otherwise, the PCOC will be carried forward as a Sitewide ECOC in the non-PMJM risk analysis in the CRA (Figure 7.4).

The output from the Sitewide ECOC screen will be a list of ECOCs for analysis of PMJM habitat and list of ECOCs for nonprotected species at the Site. The ECOCs identified in these lists will be carried on to the risk analysis processes described in the following section. All steps in the analysis will be documented in the CRA Report.

7.4 Risk Analysis Process

Action: Assess risks for the PMJM in its habitat areas and other receptors in appropriate areas Sitewide.

The following sections describe the process for conducting the risk analysis in the CRA for the Site. Two separate analyses will be used in the CRA depending on the status of the habitat designation. The risk analysis process for those areas defined as non-PMJM habitat is presented in Section 7.4.2 while the risk analysis process for the PMJM habitat area is presented in Section 7.4.3.

7.4.1 Exposure Units

The habitats and areas over which data will be aggregated will be appropriate for each receptor type. For all receptors, except PMJM, the residual risk analysis will be based on Sitewide risks in appropriate habitat. For each receptor, data from applicable abiotic media will be aggregated from habitats appropriate for the receptor.

For PMJM, no prescribed EU will be identified. Rather, habitat patches will be identified, based on the results of the PRG screening and mapping of results (see Section 7.4.3). Designation of habitat patches for further assessment will be done in consultation with the regulatory agencies.

Habitats to be included in exposure analyses will be identified for each species based on discussions with biologists from the regulatory agencies. For wildlife, vegetation community is often one of the best indicators of habitat. Extensive information is available on the types and locations of vegetation communities at RFETS (Figure 7.7). After appropriate habitats are identified for each receptor, abiotic sampling locations in these habitats will be identified and data from the locations aggregated for comparison to PRGs.

An analysis of potential data gaps will be conducted to determine whether adequate data are available in each of the EUs or habitat patches. This analysis will examine the spatial distribution of sampling locations within each EUs or habitat patch as well as evaluate the availability of adequate biotic data to characterize risk. Information gathered from the ecological monitoring program will also be evaluated in the data gaps analysis with regards to its applicability to the characterization of risk.

7.4.2 Risk Analysis Process for Non-PMJM Receptors

Risk analysis will be conducted in the CRA, following the procedures shown on Figure 7.4, for those ECOCs identified in the screening process described in Section 7.3 for non-PMJM receptors.

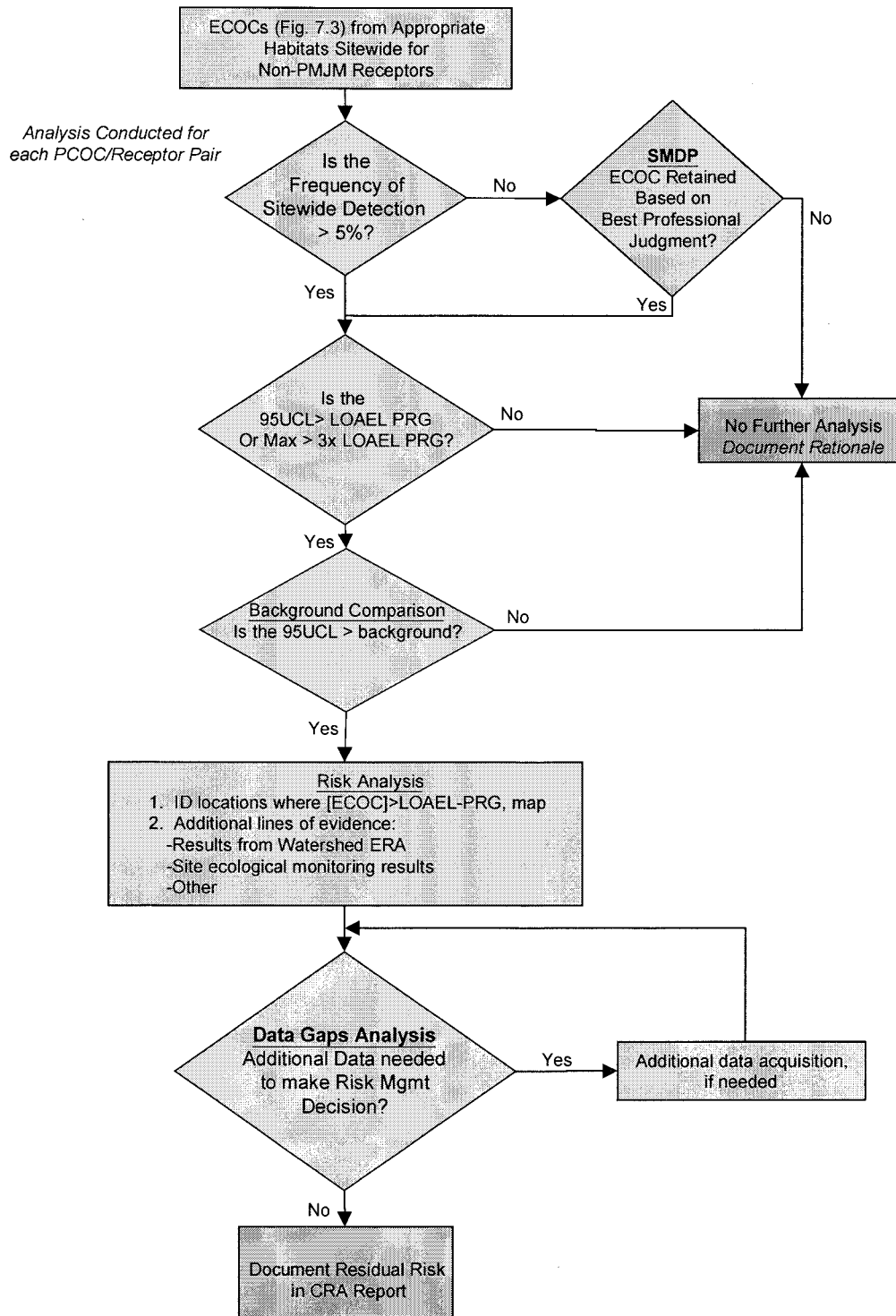
The analyses described in this section apply to all nonprotected species. The analysis will be conducted separately for each receptor, based on data on ECOC concentrations in abiotic media from habitats appropriate for each receptor. Data will be aggregated as described above from Sitewide samples and appropriate 95UCLs will be calculated. In addition, summary statistics will be calculated including percent detections, mean, standard deviation, and variance. For those ECOCs detected in 5 percent or more of sampling locations in the receptor's habitat, further risk analysis for non-PMJM receptors will be conducted. The ECOCs that are detected in less than 5 percent of samples in the receptor's habitat will be evaluated based on process knowledge, spatial and temporal factors, chemical properties (i.e., does the ECOC bioaccumulate in food webs), and toxicological properties using a best professional judgment approach for their potential to cause risk to wildlife receptors. If it is determined that no potential for risk exists, the ECOC will be recommended for no further ecological risk analysis and the rationale for the recommendation will be provided in the CRA Report.

For those ECOCs that are not eliminated based on frequency of detection, or retained based on a professional judgment decision, the 95UCL for the receptor's habitat will be compared to the LOAEL-based PRG and the maximum to three times the PRG for each relevant abiotic

medium. This comparison will be conducted for each of the ROCs. Those ECOCs for which neither the 95UCL or the maximum exceeds the comparison value will be dropped from further risk analysis. The rationale for the decision to drop an ECOC will be presented in the CRA Report.

The ECOCs for which representative concentrations exceed the LOAEL PRG will be mapped using geographic information systems (GIS) to show the locations where concentrations of the ECOC exceed the LOAEL-based PRG. Concentrations at each location will be compared to RFETS background to determine whether the Site represents incremental risk. If so, then analysis of the risks will be conducted using additional lines of evidence, such as Site ecological monitoring studies, Watershed ERA results, or other applicable sources to determine whether other data suggest risk.

Figure 7.4 CRA Risk Analysis for the Non-PMJM Receptor



79

An analysis of potential data gaps will be conducted for ECOCs that represent significant risk. If additional data are deemed to be necessary to reduce the uncertainty in the risk analysis to an acceptable level, steps will be taken to identify the types of data that may be necessary and plans to collect the additional data will be made.

Each ECOC evaluated in the risk analysis for non-PMJM habitat will be incorporated into the risk characterization portion of the CRA (Section 7.4.4). A detailed evaluation of the uncertainties involved in the risk characterization will also be included in the CRA Report.

7.4.3 Risk Analysis Process for PMJM Receptor

ECOCs identified for the PMJM receptor (Figure 7.3) will be subjected to a more conservative risk analysis process than those identified in the non-PMJM habitats due to the regulatory status of the PMJM. Section 7.3 discussed the process to be used to determine the list of ECOCs to be discussed in the risk analysis for the PMJM. The process to be used for the risk analysis for PMJM is shown on Figure 7.5.

For each ECOC identified for risk analysis in the PMJM habitats, maps will be prepared in order to identify the sampling locations in PMJM habitat for which ECOC concentrations exceed either the NOAEL-based PRGs or three times the NOAEL-based PRGs. Thiessen polygon mapping techniques will be employed to visualize the areas of potential risk to the PMJM. These maps will aid in the identification of habitat patches that will be recommended for further assessment. Concentrations will be compared to RFETS background concentrations to determine whether the location represents additional risk above natural conditions.

These maps will be reviewed with the appropriate regulatory agencies for input on further risk analysis activities. The major goal of the first agency input step is to identify patches of habitat, which can be used to aggregate data into groupings that could reasonably be expected to represent home ranges of individual PMJM. Aggregated data will be used to calculate upper-bound exposure concentrations (95UCL).

Based on regulatory agency input and best professional judgment, decisions regarding the acceptability of risk levels for the PMJM will be made. A binary decision point of acceptable or unacceptable levels of risk will be the outcome of the risk analysis process for the PMJM habitat. Additional data may also be collected if data gaps are evident. A detailed evaluation of potential data gaps will be provided prior to the determination of the potential for risk. The results of this decision point and the uncertainties associated with the potential risk to the PMJM will be discussed in detail in the CRA.

7.4.4 Ecological Risk Characterization and Uncertainty

This section describes risk characterization for ecological receptors and sources of uncertainty.

7.4.4.1 Risk Characterization

The risk analysis in the previous sections describes the process for analysis of risk data and presentation of results. As noted above, the analysis for the CRA compares data from abiotic

media to chemical- and receptor-specific PRGs. Analyses based on results of the Watershed ERA will also be used to provide additional site-specific information.

Characterization of risk will focus on the overall results for each assessment endpoint. The overall risk will be summarized for each receptor group and level of biological organization (i.e., individual- or population-level of protection), as appropriate for the assessment endpoints. As noted by EPA (1997), a well-balanced risk characterization should "...present risk conclusions and information regarding the strengths and limitations of the assessment for other risk assessors, EPA decision-makers, and the public."

Risk characterization has two main components: the risk estimation and the risk description. The risk estimation will summarize results of the analysis, identifying the receptors and ECOCs for which abiotic concentrations exceeded PRGs, and the locations at which they were exceeded. The risk description will then provide context for the analysis, including the proportions of Sitewide habitats that are affected and interpretation of overall results including data from the Watershed ERA. The risk description will also include overall risk conclusions for each assessment endpoint.

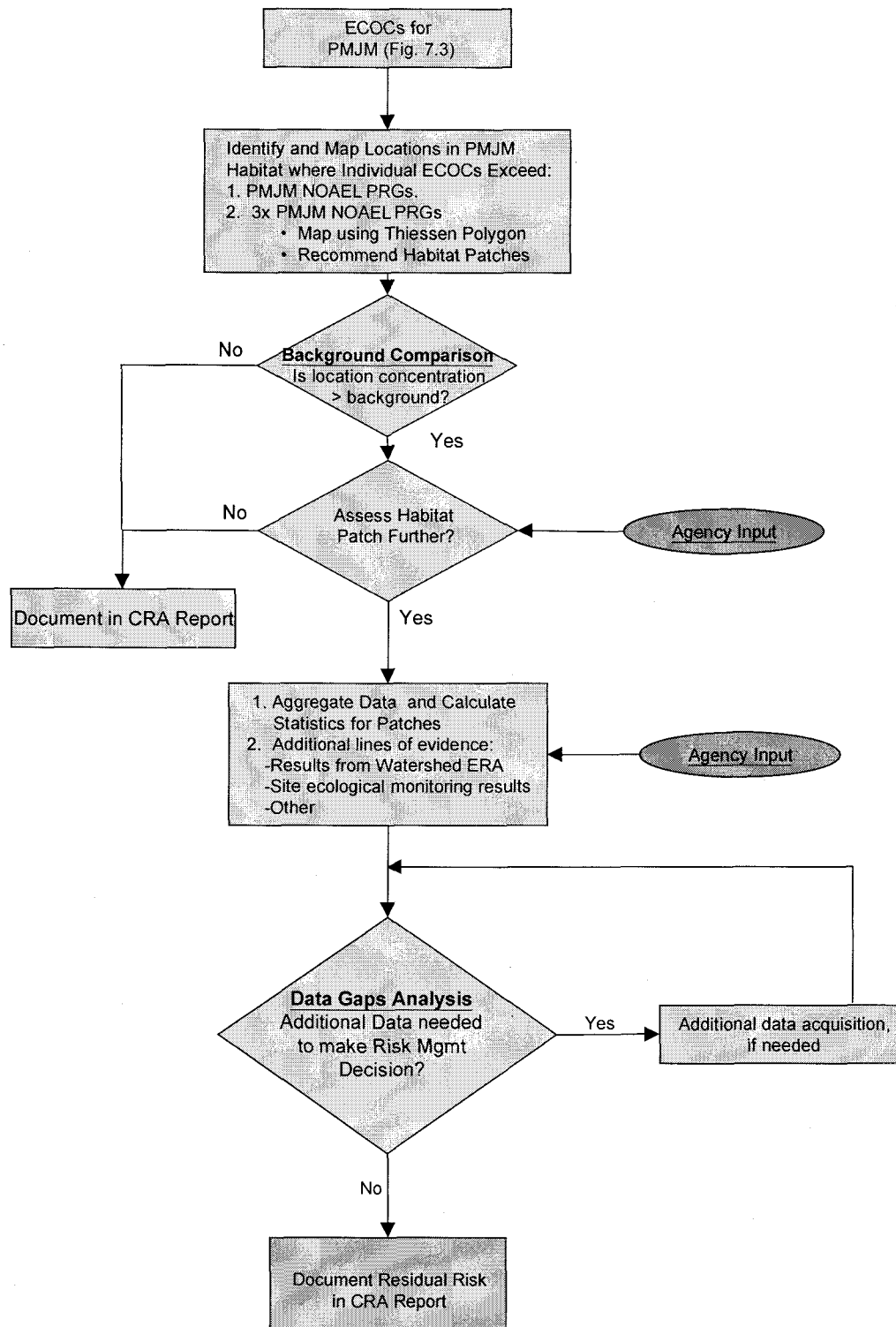
7.4.4.2 Uncertainty

The objective of the uncertainty analysis for the ERA is to identify and characterize the sources of uncertainty, and the potential effects on conclusions of the CRA. The uncertainty analysis will also identify the methods by which uncertainty for various sources were accounted for in the analysis. These uncertainties are driven by uncertainty in the Site investigation data, likelihood of hypothetical exposure scenarios, transport modes used to estimate concentrations at receptor locations, receptor intake parameters, and toxicity values used to characterize risk.

Sources of uncertainty can be related to systematic and natural variability and to chemical and physical knowledge. Variable parameters are those that reflect heterogeneity in a well-characterized population, for which the distributions would not generally be narrowed through further measurement or study. Certain parameters reflect a lack of information about the behavior or toxicity of chemicals in the system. The uncertainty analysis for the ERA will be largely qualitative, identifying the primary sources and ranking their potential importance. Quantitative estimates of uncertainty are incorporated through estimate of variability in data.

Uncertainty will be summarized for the primary components from which different kinds of uncertainty derive: sources of variability (i.e., natural and systematic) in data, exposure assessment parameters, uncertainty about ECOC toxicity thresholds, and the overall risk characterization.

Figure 7.5 CRA Risk Analysis Process for the PMJM Receptor



82

8.0 COMPREHENSIVE RISK ASSESSMENT REPORT ORGANIZATION

The CRA report will contain two volumes: the HHRA and the ERA. Summaries of the HHRA and ERA will be included in the RI/FS text. The full assessments with supporting documentation will be attached to the RI/FS report as appendices. The HHRA will contain the following sections:

Executive Summary;

Section 1.0 Introduction;

Section 2.0 Site Description;

Section 3.0 Data Quality Assessment and Adequacy;

Section 4.0 COC Identification;

Section 5.0 Exposure Assessment;

Section 6.0 Toxicity Assessment;

Section 7.0 Risk Characterization and Uncertainty Analysis;

Section 8.0 Summary; and

Section 9.0 References.

The ERA will contain the following sections:

Section 1.0 Introduction/Problem Statement;

Section 2.0 Conceptual Model and Assessment Endpoints;

Section 3.0 Data Quality Assessment and Adequacy;

Section 4.0 Risk Characterization and Uncertainty Analysis;

Section 5.0 Summary; and

Section 6.0 References.

Appendices for the reports will be combined to reduce redundancy and will include the following:

Data Summary - This appendix will present data used in both the HHRA and ERA reports.

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Appendix A
Draft Preliminary Remediation Goals

TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	Surface Soil PRGs	1
1.2	Subsurface Soil PRGs.....	6
1.3	Surface Water PRGs.....	11
1.4	Subsurface Soil PRGs From Volatilization	16
1.5	Groundwater PRGs From Volatilization	20
	REFERENCES	25

ACRONYMS

AOC	Area of Concern
COC	contaminant of concern
CRA	Comprehensive Risk Assessment
EU	exposure unit
ft ²	square foot
h	hour
HQ	hazard quotient
kg	kilogram
kg/mg	kilograms per milligram
km	kilometer
L/1,000 cm ³	liters per 1,000 cubic centimeters
L/day	liters per day
µg/kg	micrograms per kilogram
µm	micron
µg/m ³	micrograms per cubic meter
m	meter
m ²	square meter
m ³ /day	cubic meters per day
mg	milligram
mg/cm ²	milligrams per square centimeter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m ³	milligrams per cubic meter
mg/vol	milligrams per volume
mrem	millirem
mrem/pCi	millirems per picocurie
mrem/pCi/g	millirems per picocurie per gram
pCi	picocuries
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PRG	preliminary remediation goal
RFCA	Rocky Flats Cleanup Agreement
RFETS or Site	Rocky Flats Environmental Technology Site
WRW	wildlife refuge worker

1.0 INTRODUCTION

Preliminary Remediation Goals (PRG) are being developed to support the Draft Comprehensive Risk Assessment (CRA) at the Rocky Flats Environmental Technology Site (RFETS or Site). PRGs are being developed for organic, inorganic, and radionuclide constituents in surface soil, subsurface soil, surface water, and groundwater. These PRGs will support the derivation of contaminants of concern (COCs) at Exposure Units (EUs) and Areas of Concern (AOCs) for the CRA. These PRGs will also support an analysis of the exposure pathways associated with the Wildlife Refuge Worker (WRW). Specifically, the following sets of PRGs are being developed:

1. PRGs are being developed for organics, inorganics, and radionuclides in surface soils using the WRW exposure scenario. The PRGs being developed are based on the ingestion, inhalation, and external exposure from surface soils. These PRGs will support the development of surface soil COCs at EUs and AOCs.
2. PRGs are being developed for organics, inorganics, and radionuclides in subsurface soils using the WRW exposure scenario. The PRGs being developed are based on the ingestion, inhalation, and external exposure from subsurface soils. These PRGs will support the development of subsurface soil COCs at EUs and AOCs.
3. PRGs are being developed for organics, inorganics, and radionuclides in surface water using the WRW exposure scenario. The PRGs being developed are based on the ingestion of surface water. These PRGs will support an assessment of the surface water ingestion pathway.
4. PRGs are being developed for volatile organics in subsurface soils and groundwater using the WRW exposure scenario. The PRGs being developed are based on the inhalation of volatile organics from subsurface soils and groundwater. These PRGs will support an assessment of volatile organics in subsurface soils and groundwater.

The following sections further discuss the derivation of the PRGs along with the applicable exposure parameters, PRG equations, and PRG values. The PRGs were developed using these PRG equations with the applicable PRG parameters. Toxicity factors including inhalation and ingestion slope factors and reference doses are found in the RFCA Implementation Guidance Document.

1.1 Surface Soil PRGs

The WRW Surface Soil Exposure Scenario consists of the following pathways: ingestion of surface soil, inhalation of dust (outdoors), and dermal contact for nonradionuclides for a WRW working at the Site for an average of 18.7 years, spending 50 percent of this time outdoors. Inhalation of volatiles is not assessed. The external radiation exposure pathway is also included for radionuclides. The worker is envisioned spending all of their time on the most contaminated areas of the Site, and performs soil contact-intensive activities. This scenario includes all complete and significant exposure pathways and parameter assumptions that were evaluated in the Task 3 Report and Appendices: Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA et al. 2002). PRGs were calculated for both 1E-06 risk and a hazard quotient (HQ) of 0.1.

PRGs for radionuclides are 10 percent of the value recorded in RFCA (DOE et al. 1996), for soils (equivalent to a carcinogenic risk of 1E-06). The more conservative of the two values is chosen for the PRG.

1.1.1 PRG Parameters

The following PRG parameters are used to derive PRGs using the PRG equations listed below.

Exposure Parameter	Variable	Unit	Point Estimate
Target hazard index - 1	THI-1	--	0.1
Target excess lifetime cancer risk - 1	TR-1	--	1E-06
Adult body weight	BW _a	kg	70
Averaging time - noncarcinogenic	AT _{nc}	yr	18.7
Averaging time - carcinogenic	AT _c	yr	70
Exposure frequency	EF _{wss}	day/yr	250
Exposure duration	ED _w	yr	18.7
Exposure time-outdoors	ET _{o_w}	hr/day	4
Hourly inhalation rate - worker	IR _{aw}	m ³ /hr	1.30
Mass Loading, (PM10) for inhalation	MLF	kg/m ³	6.7 E-8
Site-specific PEF based on ML	PEF	m ³ /kg	14925373
Soil/Sediment Ingestion Rate	IR _{wss}	mg/day	100
Exposure time fraction, outdoor	ET _{Fo_w}	--	1
Exposure time fraction, indoor	ET _{Fi_w}	--	0
WRW skin-soil adherence factor	AF _w	mg/cm ² -event	0.117
Event frequency	EV _w	events/d	1
WRW skin surface area	SA _w	cm ²	3300.00
Dermal absorption fraction	ABS	--	chemical-specific
Oral reference dose	RfD _o	mg/kg-day	chemical-specific
Oral cancer slope factor	CSF _o	(mg/kg-day) ⁻¹	chemical-specific
Inhalation reference dose	RfD _i	mg/kg-day	chemical-specific
Inhalation cancer slope factor	CSF _i	(mg/kg-day) ⁻¹	chemical-specific

1.1.2 PRG Equations

The following PRG equations are used to derive the PRG values.

Noncarcinogenic PRG =

$$((\text{THI} \times \text{ATnc}(\text{y}) \times 365(\text{d/y})) / (\text{IRwss}(\text{mg/d}) \times \text{EFwss}(\text{d/y}) \times \text{EDw}(\text{y}) \times 10^{-6}(\text{kg/mg}) \times 1/\text{RfDo}(\text{mg/kgd}) \times 1/\text{BWa}(\text{kg}))) + (\text{IRaw}(\text{m}^3/\text{h}) \times \text{EFwss}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ETo_w}(\text{h/d}) \times 1/\text{PEF}(\text{m}^3/\text{kg}) \times 1/\text{RfDi}(\text{mg/kgd}) \times 1/\text{BWa}(\text{kg}) \times (\text{ETFo_w} + (\text{ETFi_w})) + (\text{SAw}(\text{cm}^2) \times \text{AFw}(\text{mg/cm}^2 \text{ event}) \times \text{EFwss}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ABS} \times \text{EVw}(\text{events/d}) \times 1/\text{RfDo}(\text{mg/kgd}) \times 10^{-6}(\text{kg/mg}) \times 1/\text{BWa}(\text{kg}))$$

Carcinogenic PRG =

$$((\text{TR} \times \text{ATc}(\text{y}) \times 365(\text{d/y})) / (\text{IRwss}(\text{mg/d}) \times \text{EFwss}(\text{d/y}) \times \text{EDw}(\text{y}) \times 10^{-6}(\text{kg/mg}) \times \text{CSFo}(\text{risk/mg/kgd}) \times 1/\text{BWa}(\text{kg}))) + (\text{IRaw}(\text{m}^3/\text{h}) \times \text{EFwss}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ETo_w}(\text{h/d}) \times 1/\text{PEF}(\text{m}^3/\text{kg}) \times \text{CSFi}(\text{risk/mg/kgd}) \times 1/\text{BWa}(\text{kg}) \times (\text{ETFo_w} + (\text{ETFi_w})) + (\text{SAw}(\text{cm}^2) \times \text{AFw}(\text{mg/cm}^2 \text{ event}) \times \text{EFwss}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ABS} \times \text{EVw}(\text{events/d}) \times \text{CSFo}(\text{risk/mg/kgd}) \times 10^{-6}(\text{kg/mg}) \times 1/\text{BWa}(\text{kg}))$$

Equations for radionuclide PRGs can be found in the Task 3 Report and Appendices:
Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA, CDPHE, and DOE 2002).

PRG Values

	CAS Number	Noncarcinogenic Soil PRG HQ = 0.1 (mg/kg or pCi/gram)	Carcinogenic Soil PRG Risk = 1E-06 (mg/kg or pCi/gram)	Soil PRG Risk = 1E-06 or HQ = 0.1 (mg/kg or pCi/gram)
Target Analyte List				
Acenaphthene	83-32-9	4.08E+03		4.08E+03
Acetone	67-64-1	1.02E+04		1.02E+04
Aldrin	309-00-2	2.21E+00	1.62E-01	1.62E-01
Aluminum	7429-90-5	2.28E+04		2.28E+04
Anthracene	120-12-7	2.04E+04		2.04E+04
Antimony	7440-36-0	4.09E+01		4.09E+01
Aroclor 1016	12674-11-2	4.64E+00	3.54E+01	4.64E+00
Aroclor 1221	11104-28-2		1.24E+00	1.24E+00
Aroclor 1232	11141-16-5		1.24E+00	1.24E+00
Aroclor 1242	53469-21-9		1.24E+00	1.24E+00
Aroclor 1248	12672-29-6		1.24E+00	1.24E+00
Aroclor 1254	11097-69-1	1.33E+00	1.24E+00	1.24E+00
Aroclor 1260	11096-82-5		1.24E+00	1.24E+00
Arsenic	7440-38-2	2.75E+01	2.22E+00	2.22E+00
Barium	7440-39-3	2.64E+03		2.64E+03
Benzene	71-43-2	3.41E+01	2.05E+01	2.05E+01
alpha-BHC	319-84-6		5.24E-01	5.24E-01
beta-BHC	319-85-7		1.84E+00	1.84E+00
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	2.66E+01	2.55E+00	2.55E+00
Benzo(a)anthracene	56-55-3		3.49E+00	3.49E+00
Benzo(a)pyrene	50-32-8		3.49E-01	3.49E-01
Benzo(b)fluoranthene	205-99-2		3.49E+00	3.49E+00
Benzo(k)fluoranthene	207-08-9		3.49E+01	3.49E+01
Benzoic Acid (at pH 7)	65-85-0	4.09E+05		4.09E+05
Benzyl Alcohol	100-51-6	3.07E+04		3.07E+04
Beryllium	7440-41-7	9.21E+01	1.31E+02	9.21E+01

PRG Values

	CAS Number	Noncarcinogenic Soil PRG HQ = 0.1 (mg/kg or pCi/gram)	Carcinogenic Soil PRG Risk = 1E-06 (mg/kg or pCi/gram)	Soil PRG Risk = 1E-06 or HQ = 0.1 (mg/kg or pCi/gram)
Target Analyte List				
bis(2-chloroethyl)ether	111-44-4		3.48E+00	3.48E+00
bis(2-chloroisopropyl)ether	39638-32-9	4.09E+03	5.47E+01	5.47E+01
bis(2-ethylhexyl)phthalate	117-81-7	1.47E+03	1.97E+02	1.97E+02
Bromodichloromethane	75-27-4	2.04E+03	6.17E+01	6.17E+01
Bromoform	75-25-2	2.04E+03	3.73E+02	3.73E+02
Bromomethane (methyl bromide)	74-83-9	1.93E+01		1.93E+01
2-Butanone (methyl ethyl ketone)	78-93-3	1.92E+04		1.92E+04
Butylbenzylphthalate	85-68-7	1.47E+04		1.47E+04
Cadmium (water)	7440-43-9	5.11E+01	1.74E+02	5.11E+01
Cadmium (food)	7440-43-9	9.62E+01	1.74E+02	9.62E+01
Carbon disulfide	75-15-0	1.51E+03		1.51E+03
Carbon tetrachloride	56-23-5	8.15E+00	8.21E+00	8.15E+00
alpha-Chlordane	5103-71-9	4.39E+01	9.44E+00	9.44E+00
beta-Chlordane	5103-74-2	4.39E+01	9.44E+00	9.44E+00
gamma-Chlordane	12789-03-6	4.39E+01	9.44E+00	9.44E+00
4-Chloroaniline	106-47-8	2.95E+02		2.95E+02
Chlorobenzene	108-90-7	6.09E+02		6.09E+02
Chloroethane (ethyl chloride)	75-00-3	8.88E+03	1.32E+03	1.32E+03
Chloroform	67-66-3	1.92E+00	1.04E+01	1.92E+00
Chloromethane (methyl chloride)	74-87-3	1.03E+02	3.71E+01	3.71E+01
2-Chloronaphthalene	91-58-7	8.18E+03		8.18E+03
2-Chlorophenol	95-57-8	5.11E+02		5.11E+02
Chromium III	16065-83-1	1.53E+05		1.53E+05
Chromium VI	18540-29-9	2.27E+02	2.68E+01	2.68E+01
Chrysene	218-01-9		3.49E+02	3.49E+02
Cobalt	7440-48-4	1.55E+02		1.55E+02
Copper	7440-50-8	4.09E+03		4.09E+03
Cyanide	57-12-5	2.04E+03		2.04E+03
4,4-DDD	72-54-8		1.43E+01	1.43E+01
4,4-DDE	72-55-9		1.01E+01	1.01E+01
4,4-DDT	50-29-3	4.58E+01	1.01E+01	1.01E+01
Dibenz(a,h)anthracene	53-70-3		3.49E-01	3.49E-01
Dibenzofuran	132-64-9	2.95E+02		2.95E+02
Dibromochloromethane	124-48-1	1.47E+03	3.29E+01	3.29E+01
Di-n-butylphthalate	84-74-2	7.37E+03		7.37E+03
1,2-Dichlorobenzene (o-)	95-50-1	3.12E+03		3.12E+03
1,4-Dichlorobenzene (p-)	106-46-7	2.72E+03	8.40E+01	8.40E+01
3,3-Dichlorobenzidine	91-94-1		6.13E+00	6.13E+00
1,1-Dichloroethane	75-34-3	2.25E+03		2.25E+03
1,2-Dichloroethane	107-06-2	4.74E+01	1.06E+01	1.06E+01
1,1-Dichloroethene	75-35-4	9.20E+02	1.70E+00	1.70E+00
1,2-Dichloroethene (total)	540-59-0	9.20E+02		9.20E+02
2,4-Dichlorophenol (at pH 6.8)	120-83-2	3.07E+02		3.07E+02
1,2-Dichloropropane	78-87-5	3.45E+01	5.63E+01	3.45E+01
cis-1,3-Dichloropropene	10061-01-5	9.74E+02	6.57E-01	6.57E-01
trans-1,3-Dichloropropene	10061-02-6	9.74E+02	6.57E-01	6.57E-01
Dieldrin	60-57-1	3.69E+00	1.72E-01	1.72E-01
Diethylphthalate	84-66-2	5.90E+04		5.90E+04
2,4-Dimethylphenol	105-67-9	2.04E+03		2.04E+03
Dimethylphthalate	131-11-3	7.37E+05		7.37E+05
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-	534-52-1	1.02E+02		1.02E+02

96

PRG Values

	CAS Number	Noncarcinogenic Soil PRG HQ = 0.1 (mg/kg or pCi/gram)	Carcinogenic Soil PRG Risk = 1E-06 (mg/kg or pCi/gram)	Soil PRG Risk = 1E-06 or HQ = 0.1 (mg/kg or pCi/gram)
Target Analyte List				
cresol)				
2,4-Dinitrophenol	51-28-5	2.04E+02		2.04E+02
2,4-Dinitrotoluene	121-14-2	2.04E+02	5.63E+00	5.63E+00
2,6-Dinitrotoluene	606-20-2	1.02E+02	5.63E+00	5.63E+00
Di-n-octylphthalate	117-84-0	1.47E+03	7.84E+04	1.47E+03
Endosulfan I	959-98-8	4.42E+02		4.42E+02
Endosulfan II	33213-65-9	4.42E+02		4.42E+02
Endosulfan sulfate	1031-07-8	4.42E+02		4.42E+02
Endosulfan (technical)	115-29-7	4.42E+02		4.42E+02
Endrin (technical)	72-20-8	2.21E+01		2.21E+01
Ethylbenzene	100-41-4	5.62E+03	4.25E+02	4.25E+02
Fluoranthene	206-44-0	2.72E+03		2.72E+03
Fluorene	86-73-7	4.08E+03		4.08E+03
Heptachlor	76-44-8	3.69E+01	6.12E-01	6.12E-01
Heptachlor epoxide	1024-57-3	9.59E-01	3.03E-01	3.03E-01
Hexachlorobenzene	118-74-1	5.90E+01	1.72E+00	1.72E+00
Hexachlorobutadiene	87-68-3	1.47E+01	3.53E+01	1.47E+01
Hexachlorocyclopentadiene	77-47-4	3.50E+02		3.50E+02
Hexachloroethane	67-72-1	7.37E+01	1.97E+02	7.37E+01
Indeno(1,2,3-cd)pyrene	193-39-5		3.49E+00	3.49E+00
Iron	7439-89-6	3.07E+04		3.07E+04
Isophorone	78-59-1	1.47E+04	2.91E+03	2.91E+03
Lead	7439-92-1			
Lithium	7439-93-2	2.04E+03		2.04E+03
Magnesium	7439-95-4			
Manganese (Nonfood)	7439-96-5	3.48E+02		3.48E+02
Mercury (elemental)	7439-97-6	2.52E+03		2.52E+03
Methoxychlor	72-43-5	5.11E+02		5.11E+02
Methylene chloride (dichloromethane)	75-09-2	4.63E+03	2.53E+02	2.53E+02
2-Methylnaphthalene	91-57-6	2.04E+03		2.04E+03
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	1.64E+03		1.64E+03
2-Methylphenol (o-cresol)	95-48-7	3.69E+03		3.69E+03
4-Methylphenol (p-cresol)	106-44-5	3.69E+02		3.69E+02
Molybdenum	7439-98-7	5.11E+02		5.11E+02
Naphthalene	91-20-3	3.09E+02		3.09E+02
Nickel (soluble)	7440-02-0	2.04E+03		2.04E+03
2-Nitroaniline	88-74-4	1.67E+03		1.67E+03
Nitrobenzene	98-95-3	3.32E+01		3.32E+01
4-Nitrophenol	100-02-7	8.18E+02		8.18E+02
n-Nitrosodiphenylamine	86-30-6		7.81E+02	7.81E+02
n-Nitrosodipropylamine	621-64-7		5.47E-01	5.47E-01
Pentachlorophenol	87-86-5	1.56E+03	1.62E+01	1.62E+01
Phenol	108-95-2	6.13E+04		6.13E+04
Pyrene	129-00-0	2.21E+03		2.21E+03
Selenium	7782-49-2	5.11E+02		5.11E+02
Silver	7440-22-4	5.11E+02		5.11E+02
Strontium	7440-24-6	6.13E+04		6.13E+04
Stryene	100-42-5	1.23E+04		1.23E+04
1,1,2,2-Tetrachloroethane	79-34-5	6.13E+03	1.00E+01	1.00E+01
Tetrachloroethene	127-18-4	1.02E+03	6.15E+01	6.15E+01
Tin	7440-31-5	6.13E+04		6.13E+04

PRG Values

	CAS Number	Noncarcinogenic Soil PRG HQ = 0.1 (mg/kg or pCi/gram)	Carcinogenic Soil PRG Risk = 1E-06 (mg/kg or pCi/gram)	Soil PRG Risk = 1E-06 or HQ = 0.1 (mg/kg or pCi/gram)
Target Analyte List				
Toluene	108-88-3	3.13E+03		3.13E+03
Toxaphene	8001-35-2		2.50E+00	2.50E+00
1,2,4-Trichlorobenzene	120-82-1	9.23E+02		9.23E+02
1,1,1-Trichloroethane	71-55-6	7.97E+03		7.97E+03
1,1,2-Trichloroethane	79-00-5	4.09E+02	2.36E+01	2.36E+01
Trichloroethene	79-01-6	2.75E+01	1.96E+00	1.96E+00
2,4,5-Trichlorophenol	95-95-4	1.02E+04		1.02E+04
2,4,6-Trichlorophenol	88-06-2		3.47E+02	3.47E+02
Uranium (soluble salts)	No CASN	3.07E+02		3.07E+02
Vanadium	7440-62-2	7.15E+02		7.15E+02
Vinyl acetate	108-05-4	9.63E+04		9.63E+04
Vinyl chloride	75-01-4	1.25E+02	4.12E+00	4.12E+00
Xylene (total)	1330-20-7	2.04E+05		2.04E+05
Zinc	7440-66-6	3.07E+04		3.07E+04
Nitrate	14797-55-8	1.64E+05		1.64E+05
Nitrite	14797-65-0	1.02E+04		1.02E+04
Ammonium (as Ammonia)	7664-41-7	8.39E+05		8.39E+05
Fluoride (as fluoride)	7782-41-4	6.13E+03		6.13E+03
Americium-241	14596-10-2		7.60E+00	7.60E+00
Plutonium-239	10-12-8		1.16E+01	1.16E+01
Uranium-234	11-08-5		3.00E+01	3.00E+01
Uranium-235	15117-96-1		8.00E-01	8.00E-01
Uranium-238	7440-61-1		3.51E+01	3.51E+01

1.2 Subsurface Soil PRGs

The WRW Subsurface Soil Exposure Scenario consists of the following pathways: ingestion of surface soil; inhalation of dust (outdoors); and dermal contact for non-radionuclides for a WRW working at the Site for an average of 18.7 years, spending 20 days per year, 4 hours per day exposed to subsurface soil. Inhalation of volatiles is not assessed. The external radiation exposure pathway is also included for radionuclides. The worker performs soil contact-intensive activities. This scenario includes all complete and significant exposure pathways and parameter assumptions that were evaluated in the Task 3 Report and Appendices: Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA et al. 2002). PRGs were calculated for both 1E-06 risk and a HQ of 0.1. The more conservative of the two values is chosen for the PRG.

1.2.1 PRG Parameters

The following PRG parameters are used to develop PRGs using the PRG equations listed below.

Exposure Parameter	Variable	Unit	Point Estimate
Target hazard index - 1	THI-1	--	0.1
Target excess lifetime cancer risk - 1	TR-1	--	1E-06
Adult body weight	BWa	kg	70
Averaging time - noncarcinogenic	ATnc	yr	18.7
Averaging time - carcinogenic	ATc	yr	70
Exposure frequency	EFwsubs	day/yr	20
Exposure duration	EDw	yr	18.7
Exposure time-outdoors	ETo_w	hr/day	4
Hourly inhalation rate adult worker	IRaw	m ³ /hr	1.30
Mass Loading, (PM10) for inhalation	MLF	kg/m ³	6.7 E-8
Site-specific PEF based on ML	PEF	m ³ /kg	14925373
Soil Ingestion Rate	IRwss	mg/day	100
Exposure time fraction, outdoor	ETFo_w	--	1
Exposure time fraction, indoor	ETFi_w	--	0
WRW skin-soil adherence factor	v	mg/cm ² -event	0.117
Event frequency	EVw	events/d	1
WRW skin surface area	SAw	cm ²	3300
Dermal absorption fraction	ABS	--	chemical-specific
Gamma shielding factor (1-Se)	GSF	--	0
Area Correction Factor	ACF	--	0.9
Oral reference dose	RfDo	mg/kg-day	chemical-specific
Oral cancer slope factor	CSFo	(mg/kg-day) ⁻¹	chemical-specific
Inhalation reference dose	RfDi	mg/kg-day	chemical-specific
Inhalation cancer slope factor	CSFi	(mg/kg-day) ⁻¹	chemical-specific

1.2.2 PRG Equations

The following PRG equations are used to derive the PRG values.

Noncarcinogenic PRG =

$$((\text{THI} \times \text{ATnc}(\text{y}) \times 365(\text{d/y})) / (\text{IRwss}(\text{mg/d}) \times \text{EFwsubs}(\text{d/y}) \times \text{EDw}(\text{y}) \times 10^{-6}(\text{kg/mg}) \times 1/\text{RfDo}(\text{mg/kgd}) \times 1/\text{BWa}(\text{kg}))) + (\text{IRaw}(\text{m}^3/\text{d}) \times \text{EFwsubs}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ETo_w}(\text{h/d}) \times 1/\text{PEF}(\text{m}^3/\text{kg}) \times 1/\text{RfDi}(\text{mg/kgd}) \times 1/\text{BWa}(\text{kg}) \times (\text{ETFo_w} + (\text{ETFi_w}))) + (\text{SAw}(\text{cm}^2) \times \text{AFw}(\text{mg/cm}^2\text{event}) \times \text{EFwsubs}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ABS} \times \text{EVw}(\text{events/d}) \times 1/\text{RfDo}(\text{mg/kgd}) \times 10^{-6}(\text{kg/mg}) \times 1/\text{BWa}(\text{kg})))$$

Carcinogenic PRG =

$$((\text{TR} \times \text{ATc}(\text{y}) \times 365(\text{d/y})) / (\text{IRwss}(\text{mg/d}) \times \text{EFwsubs}(\text{d/y}) \times \text{EDw}(\text{y}) \times 10^{-6}(\text{kg/mg}) \times \text{CSFo}(\text{risk/mg/kgd}) \times 1/\text{BWa}(\text{kg}))) + (\text{IRaw}(\text{m}^3/\text{h}) \times \text{EFwsubs}(\text{d/y}) \times \text{EDw}(\text{y}) \times \text{ETo_w}(\text{h/d}) \times 1/\text{PEF}(\text{m}^3/\text{kg}) \times \text{CSFi}(\text{risk/mg/kgd}) \times 1/\text{BWa}(\text{kg}) \times (\text{ETFo_w} +$$

$(ETFi_w))) + (SAw(cm^2) \times AFW(mg/cm^2 \text{ event}) \times EFwsubs(d/y) \times EDw(y) \times ABS \times EVw(events/d) \times CSFo(risk/mg/kgd) \times 10^{-6}(kg/mg) \times 1/BWa(kg))$

Radionuclide Carcinogenic PRG =

$(TR / (IRwss(mg/d) \times CSF_{soil} FRG13(risk/pCi) \times 10^{-3}(g/mg) \times EFwsubs(d/y) \times EDw(y)) + (IRaw(m^3/h) \times 1/PEF(m^3/kg) \times CSFi FRG13(risk/pCi) \times 1000(g/kg) \times EFwsubs(d/y) \times EDw(y) \times ETo_w(h/d) \times (ETo_WRW + (ETi_WRW \times DFi))) + (CSFe FRG13(risk/y/pCi/g) \times EF_WRW(d/y)/365(d/y) \times Eto_w(h/d)/24 \times ED_WRW(y) \times ACF) \backslash$

PRG Values

		Adult WLRW	Adult WLRW	Adult WLRW
		Noncarcinogenic	Carcinogenic	Soil PRG
	CAS Number	Subsoil RBC HQ = 0.1 (mg/kg)	Subsoil RBC Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/kg)
Target Analyte List				
Acenaphthene	83-32-9	5.10E+04		5.10E+04
Acetone	67-64-1	1.28E+05		1.28E+05
Aldrin	309-00-2	2.76E+01	2.02E+00	2.02E+00
Aluminum	7429-90-5	2.85E+05		2.85E+05
Anthracene	120-12-7	2.55E+05		2.55E+05
Antimony	7440-36-0	5.11E+02		5.11E+02
Aroclor 1016	12674-11-2	5.80E+01	4.42E+02	5.80E+01
Aroclor 1221	11104-28-2		1.55E+01	1.55E+01
Aroclor 1232	11141-16-5		1.55E+01	1.55E+01
Aroclor 1242	53469-21-9		1.55E+01	1.55E+01
Aroclor 1248	12672-29-6		1.55E+01	1.55E+01
Aroclor 1254	11097-69-1	1.66E+01	1.55E+01	1.55E+01
Aroclor 1260	11096-82-5		1.55E+01	1.55E+01
Arsenic	7440-38-2	3.43E+02	2.77E+01	2.77E+01
Barium	7440-39-3	3.30E+04		3.30E+04
Benzene	71-43-2	4.26E+02	2.57E+02	2.57E+02
alpha-BHC	319-84-6		6.56E+00	6.56E+00
beta-BHC	319-85-7		2.29E+01	2.29E+01
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	3.32E+02	3.19E+01	3.19E+01
Benzo(a)anthracene	56-55-3		4.36E+01	4.36E+01
Benzo(a)pyrene	50-32-8		4.36E+00	4.36E+00
Benzo(b)fluoranthene	205-99-2		4.36E+01	4.36E+01
Benzo(k)fluoranthene	207-08-9		4.36E+02	4.36E+02
Benzoic Acid (at pH 7)	65-85-0	5.11E+06		5.11E+06
Benzyl Alcohol	100-51-6	3.83E+05		3.83E+05
Beryllium	7440-41-7	1.15E+03	1.63E+03	1.15E+03
bis(2-chloroethyl)ether	111-44-4		4.35E+01	4.35E+01
bis(2-chloroisopropyl)ether	39638-32-9	5.11E+04	6.83E+02	6.83E+02
bis(2-ethylhexyl)phthalate	117-81-7	1.84E+04	2.46E+03	2.46E+03
Bromodichloromethane	75-27-4	2.56E+04	7.71E+02	7.71E+02
Bromoform	75-25-2	2.56E+04	4.66E+03	4.66E+03
Bromomethane (methyl bromide)	74-83-9	2.41E+02		2.41E+02
2-Butanone (methyl ethyl ketone)	78-93-3	2.41E+05		2.41E+05
Butylbenzylphthalate	85-68-7	1.84E+05		1.84E+05
Cadmium (water)	7440-43-9	6.39E+02	2.18E+03	6.39E+02
Cadmium (food)	7440-43-9	1.20E+03	2.18E+03	1.20E+03
Carbon disulfide	75-15-0	1.88E+04		1.88E+04

PRG Values

		Adult WLRW	Adult WLRW	Adult WLRW
		Noncarcinogenic	Carcinogenic	Soil PRG
	CAS Number	Subsoil RBC HQ = 0.1 (mg/kg)	Subsoil RBC Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/kg)
Target Analyte List				
Carbon tetrachloride	56-23-5	1.02E+02	1.03E+02	1.02E+02
alpha-Chlordane	5103-71-9	5.49E+02	1.18E+02	1.18E+02
beta-Chlordane	5103-74-2	5.49E+02	1.18E+02	1.18E+02
gamma-Chlordane	12789-03-6	5.49E+02	1.18E+02	1.18E+02
4-Chloroaniline	106-47-8	3.69E+03		3.69E+03
Chlorobenzene	108-90-7	7.61E+03		7.61E+03
Chloroethane (ethyl chloride)	75-00-3	1.11E+05	1.65E+04	1.65E+04
Chloroform	67-66-3	2.40E+01	1.30E+02	2.40E+01
Chloromethane (methyl chloride)	74-87-3	1.29E+03	4.64E+02	4.64E+02
2-Chloronaphthalene	91-58-7	1.02E+05		1.02E+05
2-Chlorophenol	95-57-8	6.39E+03		6.39E+03
Chromium III	16065-83-1	1.92E+06		1.92E+06
Chromium VI	18540-29-9	2.84E+03	3.35E+02	3.35E+02
Chrysene	218-01-9		4.36E+03	4.36E+03
Cobalt	7440-48-4	1.93E+03		1.93E+03
Copper	7440-50-8	5.11E+04		5.11E+04
Cyanide	57-12-5	2.56E+04		2.56E+04
4,4-DDD	72-54-8		1.79E+02	1.79E+02
4,4-DDE	72-55-9		1.26E+02	1.26E+02
4,4-DDT	50-29-3	5.72E+02	1.26E+02	1.26E+02
Dibenz(a,h)anthracene	53-70-3		4.36E+00	4.36E+00
Dibenzofuran	132-64-9	3.69E+03		3.69E+03
Dibromochloromethane	124-48-1	1.84E+04	4.11E+02	4.11E+02
Di-n-butylphthalate	84-74-2	9.22E+04		9.22E+04
1,2-Dichlorobenzene (o-)	95-50-1	3.90E+04		3.90E+04
1,4-Dichlorobenzene (p-)	106-46-7	3.40E+04	1.05E+03	1.05E+03
3,3-Dichlorobenzidine	91-94-1		7.67E+01	7.67E+01
1,1-Dichloroethane	75-34-3	2.81E+04		2.81E+04
1,2-Dichloroethane	107-06-2	5.93E+02	1.32E+02	1.32E+02
1,1-Dichloroethene	75-35-4	1.15E+04	2.13E+01	2.13E+01
1,2-Dichloroethene (total)	540-59-0	1.15E+04		1.15E+04
2,4-Dichlorophenol (at pH 6.8)	120-83-2	3.83E+03		3.83E+03
1,2-Dichloropropane	78-87-5	4.32E+02	7.03E+02	4.32E+02
cis-1,3-Dichloropropene	10061-01-5	1.22E+04	8.21E+00	8.21E+00
trans-1,3-Dichloropropene	10061-02-6	1.22E+04	8.21E+00	8.21E+00
Dieldrin	60-57-1	4.61E+01	2.15E+00	2.15E+00
Diethylphthalate	84-66-2	7.37E+05		7.37E+05
2,4-Dimethylphenol	105-67-9	2.56E+04		2.56E+04
Dimethylphthalate	131-11-3	9.22E+06		9.22E+06
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1	1.28E+03		1.28E+03
2,4-Dinitrophenol	51-28-5	2.56E+03		2.56E+03
2,4-Dinitrotoluene	121-14-2	2.56E+03	7.03E+01	7.03E+01
2,6-Dinitrotoluene	606-20-2	1.28E+03	7.03E+01	7.03E+01
Di-n-octylphthalate	117-84-0	1.84E+04	9.80E+05	1.84E+04
Endosulfan I	959-98-8	5.53E+03		5.53E+03
Endosulfan II	33213-65-9	5.53E+03		5.53E+03
Endosulfan sulfate	1031-07-8	5.53E+03		5.53E+03
Endosulfan (technical)	115-29-7	5.53E+03		5.53E+03
Endrin (technical)	72-20-8	2.76E+02		2.76E+02
Ethylbenzene	100-41-4	7.02E+04	5.31E+03	5.31E+03

PRG Values

		Adult WLRW	Adult WLRW	Adult WLRW
		Noncarcinogenic	Carcinogenic	Soil PRG
	CAS Number	Subsoil RBC HQ = 0.1 (mg/kg)	Subsoil RBC Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/kg)
Target Analyte List				
Fluoranthene	206-44-0	3.40E+04		3.40E+04
Fluorene	86-73-7	5.10E+04		5.10E+04
Heptachlor	76-44-8	4.61E+02	7.65E+00	7.65E+00
Heptachlor epoxide	1024-57-3	1.20E+01	3.78E+00	3.78E+00
Hexachlorobenzene	118-74-1	7.37E+02	2.15E+01	2.15E+01
Hexachlorobutadiene	87-68-3	1.84E+02	4.41E+02	1.84E+02
Hexachlorocyclopentadiene	77-47-4	4.37E+03		4.37E+03
Hexachloroethane	67-72-1	9.22E+02	2.46E+03	9.22E+02
Indeno(1,2,3-cd)pyrene	193-39-5		4.36E+01	4.36E+01
Iron	7439-89-6	3.83E+05		3.83E+05
Isophorone	78-59-1	1.84E+05	3.63E+04	3.63E+04
Lead	7439-92-1			
Lithium	7439-93-2	2.56E+04		2.56E+04
Magnesium	7439-95-4			
Manganese (Nonfood)	7439-96-5	4.35E+03		4.35E+03
Mercury (elemental)	7439-97-6	3.15E+04		3.15E+04
Methoxychlor	72-43-5	6.39E+03		6.39E+03
Methylene chloride (dichloromethane)	75-09-2	5.79E+04	3.16E+03	3.16E+03
2-Methylnaphthalene	91-57-6	2.56E+04		2.56E+04
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	2.05E+04		2.05E+04
2-Methylphenol (o-cresol)	95-48-7	4.61E+04		4.61E+04
4-Methylphenol (p-cresol)	106-44-5	4.61E+03		4.61E+03
Molybdenum	7439-98-7	6.39E+03		6.39E+03
Naphthalene	91-20-3	3.87E+03		3.87E+03
Nickel (soluble)	7440-02-0	2.56E+04		2.56E+04
2-Nitroaniline	88-74-4	2.09E+04		2.09E+04
Nitrobenzene	98-95-3	4.15E+02		4.15E+02
4-Nitrophenol	100-02-7	1.02E+04		1.02E+04
n-Nitrosodiphenylamine	86-30-6		9.76E+03	9.76E+03
n-Nitrosodipropylamine	621-64-7		6.83E+00	6.83E+00
Pentachlorophenol	87-86-5	1.95E+04	2.03E+02	2.03E+02
Phenol	108-95-2	7.67E+05		7.67E+05
Pyrene	129-00-0	2.76E+04		2.76E+04
Selenium	7782-49-2	6.39E+03		6.39E+03
Silver	7440-22-4	6.39E+03		6.39E+03
Strontium	7440-24-6	7.67E+05		7.67E+05
Stryene	100-42-5	1.54E+05		1.54E+05
1,1,2,2-Tetrachloroethane	79-34-5	7.67E+04	1.25E+02	1.25E+02
Tetrachloroethene	127-18-4	1.28E+04	7.68E+02	7.68E+02
Tin	7440-31-5	7.67E+05		7.67E+05
Toluene	108-88-3	3.91E+04		3.91E+04
Toxaphene	8001-35-2		3.13E+01	3.13E+01
1,2,4-Trichlorobenzene	120-82-1	1.15E+04		1.15E+04
1,1,1-Trichloroethane	71-55-6	9.97E+04		9.97E+04
1,1,2-Trichloroethane	79-00-5	5.11E+03	2.95E+02	2.95E+02
Trichloroethene	79-01-6	3.43E+02	2.45E+01	2.45E+01
2,4,5-Trichlorophenol	95-95-4	1.28E+05		1.28E+05
2,4,6-Trichlorophenol	88-06-2		4.33E+03	4.33E+03
Uranium (soluble salts)	No CASN	3.83E+03		3.83E+03

PRG Values

		Adult WLRW	Adult WLRW	Adult WLRW
		Noncarcinogenic	Carcinogenic	Soil PRG
	CAS Number	Subsoil RBC HQ = 0.1 (mg/kg)	Subsoil RBC Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/kg)
Target Analyte List				
Vanadium	7440-62-2	8.94E+03		8.94E+03
Vinyl acetate	108-05-4	1.20E+06		1.20E+06
Vinyl chloride	75-01-4	1.56E+03	5.15E+01	5.15E+01
Xylene (total)	1330-20-7	2.56E+06		2.56E+06
Zinc	7440-66-6	3.83E+05		3.83E+05
Nitrate	14797-55-8	2.04E+06		2.04E+06
Nitrite	14797-65-0	1.28E+05		1.28E+05
Ammonium (as Ammonia)	7664-41-7	1.05E+07		1.05E+07
Fluoride (as fluorine)	7782-41-4	7.67E+04		7.67E+04
			(pCi/g)	
Am-241	14596-10-2		6.24E+01	6.24E+01
Pu-239	15117-48-3		6.79E+01	6.79E+01
Pu-240	14119-33-6		6.80E+01	6.80E+01
U-233	13968-55-3	3.83E+03	1.31E+02	1.31E+02
U-234	13966-29-5	3.83E+03	1.35E+02	1.35E+02
U-235	15117-96-1	3.83E+03	1.15E+01	1.15E+01
U-235+D	15117-96-1(+D)	3.83E+03	1.10E+01	1.10E+01
U-238	7440-61-1	3.83E+03	1.52E+02	1.52E+02
U-238+D	7440-61-1(+D)	3.83E+03	3.76E+01	3.76E+01

1.3 Surface Water PRGs

The WRW Surface Water Exposure Scenario consists of the following pathway: ingestion of surface water on the Site for 18.7 years. This scenario was not considered to be a significant exposure pathway in the Task 3 Report and Appendices: Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA et al. 2002). Calculations in this spreadsheet are performed deterministically. PRGs were calculated for both 1E-06 risk and a HQ of 0.1.

1.3.1 PRG Parameters

The following PRG parameters are used to develop PRGs using the PRG equations listed below.

Exposure Parameter	Variable	Unit	Point Estimate
General Assumptions			
Target hazard index-1	THI-1	--	0.1
Target excess lifetime cancer risk-1	TR-1	--	1E-06
Adult body weight	BW _a	kg	70
Residential Exposure Scenario Assumptions			
Averaging time - noncarcinogenic	AT _{nc}	yr	18.7
Averaging time - carcinogenic	AT _c	yr	70
Exposure frequency - surface water	EF _{sw}	day/yr	42

Exposure Parameter	Variable	Unit	Point Estimate
Exposure duration	EDw	yr	18.7
Surface water incidental ingestion rate	IRsw	L/day	0.03
Toxicity Values			
Oral reference dose	RfDo	mg/kg-day	chemical-specific
Oral cancer slope factor	CSFo	risk/(mg/kg-d)	chemical-specific
Inhalation reference dose	RfDi	mg/kg-day	chemical-specific
Inhalation cancer slope factor	CSFi	risk/(mg/kg-d)	chemical-specific

1.3.2 PRG Equations

The following PRG equations are used to derive the PRG values.

Noncarcinogenic PRG =

$$((THI \times ATnc(y) \times 365(d/y)) / (IRsw(L/d) \times EFsw(d/y) \times EDw(y) \times 1/RfDo(mg/kgd) \times 1/BWa(kg)))$$

Carcinogenic PRG =

$$((TR \times ATc(y) \times 365(d/y)) / (IRsw(L/d) \times EFsw(d/y) \times EDw(y) \times CSFo(risk/mg/kgd) \times (1/BWa(kg))))$$

Radionuclide carcinogenic PRG =

$$(TR / (IRsw(L/d) \times EFsw(d/y) \times EDw(y) \times CSFw \text{ FRG13}(risk/pCi)))$$

PRG Values

		Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic	Carcinogenic	Surface Water
	CAS Number	Surface Water HQ = 0.1 (mg/kg)	Surface Water Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/L)
Target Analyte List				
Chemical				
Acenaphthene	83-32-9	1.22E+02		1.22E+02
Acetone	67-64-1	2.03E+02		2.03E+02
Aldrin	309-00-2	6.08E-02	4.47E-03	4.47E-03
Aluminum	7429-90-5	2.03E+03		2.03E+03
Anthracene	120-12-7	6.08E+02		6.08E+02
Antimony	7440-36-0	8.11E-01		8.11E-01
Aroclor 1016	12674-11-2	1.42E-01	1.08E+00	1.42E-01
Aroclor 1221	11104-28-2		3.80E-02	3.80E-02
Aroclor 1232	11141-16-5		3.80E-02	3.80E-02
Aroclor 1242	53469-21-9		3.80E-02	3.80E-02
Aroclor 1248	12672-29-6		3.80E-02	3.80E-02

PRG Values

		Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic	Carcinogenic	Surface Water
	CAS Number	Surface Water HQ = 0.1 (mg/kg)	Surface Water Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/L)
Target Analyte List				
Aroclor 1254	11097-69-1	4.06E-02	3.80E-02	3.80E-02
Aroclor 1260	11096-82-5		3.80E-02	3.80E-02
Arsenic	7440-38-2	6.08E-01	5.06E-02	5.06E-02
Barium	7440-39-3	1.42E+02		1.42E+02
Benzene	71-43-2	6.08E+00	1.38E+00	1.38E+00
alpha-BHC	319-84-6		1.20E-02	1.20E-02
beta-BHC	319-85-7		4.22E-02	4.22E-02
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	6.08E-01	5.84E-02	5.84E-02
Benzo(a)anthracene	56-55-3		1.04E-01	1.04E-01
Benzo(a)pyrene	50-32-8		1.04E-02	1.04E-02
Benzo(b)fluoranthene	205-99-2		1.04E-01	1.04E-01
Benzo(k)fluoranthene	207-08-9		1.04E+00	1.04E+00
Benzoic Acid (at pH 7)	65-85-0	8.11E+03		8.11E+03
Benzyl Alcohol	100-51-6	6.08E+02		6.08E+02
Beryllium	7440-41-7	4.06E+00		4.06E+00
bis(2-chloroethyl)ether	111-44-4		6.90E-02	6.90E-02
bis(2-chloroisopropyl)ether	39638-32-9	8.11E+01	1.08E+00	1.08E+00
bis(2-ethylhexyl)phthalate	117-81-7	4.06E+01	5.42E+00	5.42E+00
Bromodichloromethane	75-27-4	4.06E+01	1.22E+00	1.22E+00
Bromoform	75-25-2	4.06E+01	9.61E+00	9.61E+00
Bromomethane (methyl bromide)	74-83-9	2.84E+00		2.84E+00
2-Butanone (methyl ethyl ketone)	78-93-3	1.22E+03		1.22E+03
Butylbenzylphthalate	85-68-7	4.06E+02		4.06E+02
Cadmium (food)	7440-43-9			
Cadmium (water)	7440-43-9	1.01E+00		1.01E+00
Carbon disulfide	75-15-0	2.03E+02		2.03E+02
Carbon tetrachloride	56-23-5	1.42E+00	5.84E-01	5.84E-01
alpha-Chlordane	5103-71-9	1.01E+00	2.17E-01	2.17E-01
beta-Chlordane	5103-74-2	1.01E+00	2.17E-01	2.17E-01
gamma-Chlordane	12789-03-6	1.01E+00	2.17E-01	2.17E-01
4-Chloroaniline	106-47-8	8.11E+00		8.11E+00
Chlorobenzene	108-90-7	4.06E+01		4.06E+01
Chloroethane (ethyl chloride)	75-00-3	8.11E+02	2.62E+01	2.62E+01
Chloroform	67-66-3	2.03E+01		2.03E+01
Chloromethane (methyl chloride)	74-87-3		5.84E+00	5.84E+00
2-Chloronaphthalene	91-58-7	1.62E+02		1.62E+02
2-Chlorophenol	95-57-8	1.01E+01		1.01E+01
Chromium III	16065-83-1	3.04E+03		3.04E+03
Chromium VI	18540-29-9	6.08E+00		6.08E+00
Chrysene	218-01-9		1.04E+01	1.04E+01
Cobalt	7440-48-4	4.06E+01		4.06E+01
Copper	7440-50-8	8.11E+01		8.11E+01
Cyanide	57-12-5	4.06E+01		4.06E+01
4,4-DDD	72-54-8		3.16E-01	3.16E-01
4,4-DDE	72-55-9		2.23E-01	2.23E-01

PRG Values

		Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic	Carcinogenic	Surface Water
	CAS Number	Surface Water HQ = 0.1 (mg/kg)	Surface Water Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/L)
Target Analyte List				
4,4-DDT	50-29-3	1.01E+00	2.23E-01	2.23E-01
Dibenz(a,h)anthracene	53-70-3		1.04E-02	1.04E-02
Dibenzofuran	132-64-9	8.11E+00		8.11E+00
Dibromochloromethane	124-48-1	4.06E+01	9.04E-01	9.04E-01
Di-n-butylphthalate	84-74-2	2.03E+02		2.03E+02
1,2-Dichlorobenzene (o-)	95-50-1	1.83E+02		1.83E+02
1,4-Dichlorobenzene (p-)	106-46-7	6.08E+01	3.16E+00	3.16E+00
3,3-Dichlorobenzidine	91-94-1		1.69E-01	1.69E-01
1,1-Dichloroethane	75-34-3	2.03E+02		2.03E+02
1,2-Dichloroethane	107-06-2	6.08E+01	8.34E-01	8.34E-01
1,1-Dichloroethene	75-35-4	1.83E+01	1.27E-01	1.27E-01
1,2-Dichloroethene (total)	540-59-0	1.83E+01		1.83E+01
2,4-Dichlorophenol (at pH 6.8)	120-83-2	6.08E+00		6.08E+00
1,2-Dichloropropane	78-87-5		1.12E+00	1.12E+00
cis-1,3-Dichloropropene	10061-01-5	6.08E+01	7.59E-01	7.59E-01
trans-1,3-Dichloropropene	10061-02-6	6.08E+01	7.59E-01	7.59E-01
Dieldrin	60-57-1	1.01E-01	4.74E-03	4.74E-03
Diethylphthalate	84-66-2	1.62E+03		1.62E+03
2,4-Dimethylphenol	105-67-9	4.06E+01		4.06E+01
Dimethylphthalate	131-11-3	2.03E+04		2.03E+04
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1	2.03E+00		2.03E+00
2,4-Dinitrophenol	51-28-5	4.06E+00		4.06E+00
2,4-Dinitrotoluene	121-14-2	4.06E+00	1.12E-01	1.12E-01
2,6-Dinitrotoluene	606-20-2	2.03E+00	1.12E-01	1.12E-01
Di-n-octylphthalate	117-84-0	4.06E+01		4.06E+01
Endosulfan I	959-98-8	1.22E+01		1.22E+01
Endosulfan II	33213-65-9	1.22E+01		1.22E+01
Endosulfan sulfate	1031-07-8	1.22E+01		1.22E+01
Endosulfan (technical)	115-29-7	1.22E+01		1.22E+01
Endrin (technical)	72-20-8	6.08E-01		6.08E-01
Ethylbenzene	100-41-4	2.03E+02		2.03E+02
Fluoranthene	206-44-0	8.11E+01		8.11E+01
Fluorene	86-73-7	1.22E+02		1.22E+02
Heptachlor	76-44-8	1.01E+00	1.69E-02	1.69E-02
Heptachlor epoxide	1024-57-3	2.64E-02	8.34E-03	8.34E-03
Hexachlorobenzene	118-74-1	1.62E+00	4.74E-02	4.74E-02
Hexachlorobutadiene	87-68-3	4.06E-01	9.73E-01	4.06E-01
Hexachlorocyclopentadiene	77-47-4	1.22E+01		1.22E+01
Hexachloroethane	67-72-1	2.03E+00	5.42E+00	2.03E+00
Indeno(1,2,3-cd)pyrene	193-39-5		1.04E-01	1.04E-01
Iron	7439-89-6	6.08E+02		6.08E+02
Isophorone	78-59-1	4.06E+02	7.99E+01	7.99E+01
Lead	7439-92-1			4.00E+02
Lithium	7439-93-2	4.06E+01		4.06E+01
Magnesium	7439-95-4			
Manganese (Nonfood)	7439-96-5	2.84E+02		2.84E+02

PRG Values

		Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic	Carcinogenic	Surface Water
	CAS Number	Surface Water HQ = 0.1 (mg/kg)	Surface Water Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/L)
Target Analyte List				
Mercury (elemental)	7439-97-6			
Methoxychlor	72-43-5	1.01E+01		1.01E+01
Methylene chloride (dichloromethane)	75-09-2	1.22E+02	1.01E+01	1.01E+01
2-Methylnaphthalene	91-57-6	4.06E+01		4.06E+01
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	1.62E+02		1.62E+02
2-Methylphenol (o-cresol)	95-48-7	1.01E+02		1.01E+02
4-Methylphenol (p-cresol)	106-44-5	1.01E+01		1.01E+01
Molybdenum	7439-98-7	1.01E+01		1.01E+01
Naphthalene	91-20-3	4.06E+01		4.06E+01
Nickel (soluble)	7440-02-0	4.06E+01		4.06E+01
2-Nitroaniline	88-74-4			
Nitrobenzene	98-95-3	1.01E+00		1.01E+00
4-Nitrophenol	100-02-7	1.62E+01		1.62E+01
n-Nitrosodiphenylamine	86-30-6		1.55E+01	1.55E+01
n-Nitrosodipropylamine	621-64-7		1.08E-02	1.08E-02
Pentachlorophenol	87-86-5	6.08E+01	6.33E-01	6.33E-01
Phenol	108-95-2	1.22E+03		1.22E+03
Pyrene	129-00-0	6.08E+01		6.08E+01
Selenium	7782-49-2	1.01E+01		1.01E+01
Silver	7440-22-4	1.01E+01		1.01E+01
Strontium	7440-24-6	1.22E+03		1.22E+03
Stryene	100-42-5	4.06E+02		4.06E+02
1,1,2,2-Tetrachloroethane	79-34-5	1.22E+02	3.80E-01	3.80E-01
Tetrachloroethene	127-18-4	2.03E+01	1.46E+00	1.46E+00
Tin	7440-31-5	1.22E+03		1.22E+03
Toluene	108-88-3	4.06E+02		4.06E+02
Toxaphene	8001-35-2		6.90E-02	6.90E-02
1,2,4-Trichlorobenzene	120-82-1	2.03E+01		2.03E+01
1,1,1-Trichloroethane	71-55-6	5.68E+02		5.68E+02
1,1,2-Trichloroethane	79-00-5	8.11E+00	1.33E+00	1.33E+00
Trichloroethene	79-01-6	6.08E-01	1.90E-01	1.90E-01
2,4,5-Trichlorophenol	95-95-4	2.03E+02		2.03E+02
2,4,6-Trichlorophenol	88-06-2		6.90E+00	6.90E+00
Uranium (soluble salts)	No CASN	6.08E+00		6.08E+00
Vanadium	7440-62-2	1.42E+01		1.42E+01
Vinyl acetate	108-05-4	2.03E+03		2.03E+03
Vinyl chloride	75-01-4	6.08E+00	1.05E-01	1.05E-01
Xylene (total)	1330-20-7	4.06E+03		4.06E+03
Zinc	7440-66-6	6.08E+02		6.08E+02
Nitrate	14797-55-8	3.24E+03		3.24E+03
Nitrite	14797-65-0	2.03E+02		2.03E+02
Ammonium (as Ammonia)	7664-41-7			
Fluoride (as fluorine)	7782-41-4	1.22E+02		1.22E+02
				(pCi/L)
Am-241	14596-10-2			4.08E+02

PRG Values

		Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic	Carcinogenic	Surface Water
	CAS Number	Surface Water HQ = 0.1 (mg/kg)	Surface Water Risk = 1E-06 (mg/kg)	Risk = 1E-06 or HQ = 0.1 (mg/L)
Target Analyte List				
Pu-239	15117-48-3			3.14E+02
Pu-240	14119-33-6			3.14E+02
U-233	13968-55-3			5.91E+02
U-234	13966-29-5			6.08E+00
U-235	15117-96-1			6.08E+00
U-235+D	15117-96-1(+D)			6.08E+00
U-238	7440-61-1			6.08E+00
U-238+D	7440-61-1(+D)			6.08E+00

1.4 Subsurface Soil PRGs From Volatilization

The WRW Subsurface Soil Exposure Scenario associated with volatilization consists of the following pathway: indoor inhalation of volatile organics emanating from subsurface soils for a WRW working at the Site for an average of 18.7 years, spending 50 percent of this time indoors. The worker is envisioned spending all of their time on the most contaminated areas of the Site. This scenario includes all complete and significant exposure pathways and parameter assumptions that were evaluated in the Task 3 Report and Appendices: Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA et al. 2002). PRGs were calculated for both 1E-06 risk and a hazard quotient (HQ) of 0.1. The more conservative of the two values is chosen for the PRG.

1.4.1 PRG Parameters & Equations

Johnson and Ettinger introduced a screening-level model which incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above the source of contamination. The Johnson and Ettinger model is a one-dimensional analytical solution to convective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination. Inputs to the model include chemical properties of the contaminant, saturated and unsaturated zone soil properties, and structural properties of the building.

The Johnson and Ettinger model was used to calculate the PRGs below with site-specific and default modeling parameters. See the user manual for the model (Johnson & Ettinger 2000) for a discussion of modeling parameters.

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBC HQ = 0.1 Site-spec VF (ug/kg)	WLRW Carc. inhal. RBC Risk = 1E-06 site-spec VF (ug/kg)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/kg)
Acenaphthene	83-32-9	1.77E+05		1.77E+05
Acetone	67-64-1	3.10E+05		3.10E+05
Aldrin	309-00-2		2.92E+05	2.92E+05
Aluminum	7429-90-5			
Anthracene	120-12-7			
Antimony	7440-36-0			
Aroclor 1016	12674-11-2			
Aroclor 1221	11104-28-2			
Aroclor 1232	11141-16-5			
Aroclor 1242	53469-21-9			
Aroclor 1248	12672-29-6			
Aroclor 1254	11097-69-1			
Aroclor 1260	11096-82-5			
Arsenic	7440-38-2			
Barium	7440-39-3			
Benzene	71-43-2		1.30E+00	1.30E+00
alpha-BHC	319-84-6		1.14E+04	1.14E+04
beta-BHC	319-85-7			
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	3.98E+05	3.82E+04	3.82E+04
Benzo(a)anthracene	56-55-3			
Benzo(a)pyrene	50-32-8			
Benzo(b)fluoranthene	205-99-2			
Benzo(k)fluoranthene	207-08-9			
Benzoic Acid (at pH 7)	65-85-0			
Benzyl Alcohol	100-51-6			
Beryllium	7440-41-7			
bis(2-chloroethyl)ether	111-44-4		6.09E+02	6.09E+02
bis(2-chloroisopropyl)ether	39638-32-9			
bis(2-ethylhexyl)phthalate	117-81-7			
Bromodichloromethane	75-27-4	8.18E+03	2.47E+02	2.47E+02
Bromoform	75-25-2	1.97E+04	4.05E+04	1.97E+04
Bromomethane (methyl bromide)	74-83-9	4.12E+01		4.12E+01
2-Butanone (methyl ethyl ketone)	78-93-3	7.37E+05		7.37E+05
Butylbenzylphthalate	85-68-7			
Cadmium (water)	7440-43-9			
Cadmium (food)	7440-43-9			
Carbon disulfide	75-15-0	2.72E+03		2.72E+03
Carbon tetrachloride	56-23-5		3.05E+01	3.05E+01
alpha-Chlordane	5103-71-9			

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBC HQ = 0.1 Site-spec VF (ug/kg)	WLRW Carc. inhal. RBC Risk = 1E-06 site-spec VF (ug/kg)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/kg)
beta-Chlordane	5103-74-2			
gamma-Chlordane	12789-03-6			
4-Chloroaniline	106-47-8			
Chlorobenzene	108-90-7	8.57E+03		8.57E+03
Chloroethane (ethyl chloride)	75-00-3	4.31E+04	1.94E+02	1.94E+02
Chloroform	67-66-3		4.71E+01	4.71E+01
Chloromethane (methyl chloride)	74-87-3	3.46E+02	1.44E+02	1.44E+02
2-Chloronaphthalene	91-58-7			
2-Chlorophenol	95-57-8	4.85E+04		4.85E+04
Chromium III	16065-83-1			
Chromium VI	18540-29-9			
Chrysene	218-01-9			
Cobalt	7440-48-4			
Copper	7440-50-8			
Cyanide	57-12-5			
4,4-DDD	72-54-8			
4,4-DDE	72-55-9			
4,4-DDT	50-29-3			
Dibenz(a,h)anthracene	53-70-3			
Dibenzofuran	132-64-9			
Dibromochloromethane	124-48-1	1.69E+04	3.77E+02	3.77E+02
Di-n-butylphthalate	84-74-2			
1,2-Dichlorobenzene (o-)	95-50-1	1.77E+05		1.77E+05
1,4-Dichlorobenzene (p-)	106-46-7			
3,3-Dichlorobenzidine	91-94-1			
1,1-Dichloroethane	75-34-3	8.65E+03		8.65E+03
1,2-Dichloroethane	107-06-2		1.07E+02	1.07E+02
1,1-Dichloroethene	75-35-4	1.05E+03		0.00E+00
1,2-Dichloroethene (total)	540-59-0			
2,4-Dichlorophenol (at pH 6.8)	120-83-2			
1,2-Dichloropropane	78-87-5	8.91E+01	1.85E+02	8.91E+01
cis-1,3-Dichloropropene	10061-01-5	1.71E+02	8.01E+01	8.01E+01
trans-1,3-Dichloropropene	10061-02-6	1.71E+02	8.01E+01	8.01E+01
Dieldrin	60-57-1		2.92E+04	2.92E+04
Diethylphthalate	84-66-2			
2,4-Dimethylphenol	105-67-9			
Dimethylphthalate	131-11-3			
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1			
2,4-Dinitrophenol	51-28-5			
2,4-Dinitrotoluene	121-14-2			
2,6-Dinitrotoluene	606-20-2			

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBC HQ = 0.1 Site-spec VF (ug/kg)	WLRW Carc. inhal. RBC Risk = 1E-06 site-spec VF (ug/kg)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/kg)
Di-n-octylphthalate	117-84-0			
Endosulfan I	959-98-8			
Endosulfan II	33213-65-9			
Endosulfan sulfate	1031-07-8			
Endosulfan (technical)	115-29-7			
Endrin (technical)	72-20-8			
Ethylbenzene	100-41-4	1.11E+05	3.79E+03	3.79E+03
Fluoranthene	206-44-0			
Fluorene	86-73-7	1.92E+05		1.92E+05
Heptachlor	76-44-8	1.63E+04	2.68E+02	2.68E+02
Heptachlor epoxide	1024-57-3			
Hexachlorobenzene	118-74-1			
Hexachlorobutadiene	87-68-3	1.40E+05	3.40E+04	3.40E+04
Hexachlorocyclopentadiene	77-47-4	8.12E+03		8.12E+03
Hexachloroethane	67-72-1	1.80E+04	4.81E+04	1.80E+04
Indeno(1,2,3-cd)pyrene	193-39-5			
Iron	7439-89-6			
Isophorone	78-59-1			
Lead	7439-92-1			
Lithium	7439-93-2			
Magnesium	7439-95-4			
Manganese (Nonfood)	7439-96-5			
Mercury (elemental)	7439-97-6			
Methoxychlor	72-43-5			
Methylene chloride (dichloromethane)	75-09-2	7.58E+04	2.01E+03	2.01E+03
2-Methylnaphthalene	91-57-6			
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	3.68E+04		3.68E+04
2-Methylphenol (o-cresol)	95-48-7			
4-Methylphenol (p-cresol)	106-44-5			
Molybdenum	7439-98-7			
Naphthalene	91-20-3	3.67E+04		3.67E+04
Nickel (soluble)	7440-02-0			
2-Nitroaniline	88-74-4			
Nitrobenzene	98-95-3	1.85E+04		1.85E+04
4-Nitrophenol	100-02-7			
n-Nitrosodiphenylamine	86-30-6			
n-Nitrosodipropylamine	621-64-7			
Pentachlorophenol	87-86-5			
Phenol	108-95-2			
Pyrene	129-00-0			
Selenium	7782-49-2			

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBC HQ = 0.1 Site-spec VF (ug/kg)	WLRW Carc. inhal. RBC Risk = 1E-06 site-spec VF (ug/kg)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/kg)
Silver	7440-22-4			
Strontium	7440-24-6			
Stryene	100-42-5	6.82E+05		6.82E+05
1,1,2,2-Tetrachloroethane	79-34-5	1.60E+05	4.92E+02	4.92E+02
Tetrachloroethene	127-18-4		2.65E+02	2.65E+02
Tin	7440-31-5			
Toluene	108-88-3	2.50E+04		2.50E+04
Toxaphene	8001-35-2			
1,2,4-Trichlorobenzene	120-82-1	9.13E+05		9.13E+05
1,1,1-Trichloroethane	71-55-6	3.19E+04		3.19E+04
1,1,2-Trichloroethane	79-00-5	2.33E+03	3.89E+02	3.89E+02
Trichloroethene	79-01-6	1.44E+03	1.22E+01	1.22E+01
2,4,5-Trichlorophenol	95-95-4			
2,4,6-Trichlorophenol	88-06-2			
Uranium (soluble salts)	No CASN			
Vanadium	7440-62-2			
Vinyl acetate	108-05-4	2.03E+04		2.03E+04
Vinyl chloride	75-01-4	2.39E+02	1.02E+01	1.02E+01
Xylene (total)	1330-20-7			
Zinc	7440-66-6			
Nitrate	14797-55-8			
Nitrite	14797-65-0			
Ammonium (as Ammonia)	7664-41-7			
Fluoride (as fluorine)	7782-41-4			

1.5 Groundwater PRGs From Volatilization

The WRW Groundwater Exposure Scenario associated with volatilization consists of the following pathway: indoor inhalation of volatile organics emanating from groundwater for a WRW working at the Site for an average of 18.7 years, spending 50 percent of this time indoors. The worker is envisioned spending all of their time on the most contaminated areas of the Site. This scenario includes all complete and significant exposure pathways and parameter assumptions that were evaluated in the Task 3 Report and Appendices: Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA et al. 2002). PRGs were calculated for both 1E-06 risk and a hazard quotient (HQ) of 0.1. The more conservative of the two values is chosen for the PRG.

1.5.1 PRG Parameters & Equations

Johnson and Ettinger introduced a screening-level model which incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above the source of contamination. The Johnson and Ettinger model is a one-dimensional analytical solution to convective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination. Inputs to the model include chemical properties of the contaminant, saturated and unsaturated zone soil properties, and structural properties of the building.

The Johnson and Ettinger model was used to calculate the PRGs below with site-specific and default modeling parameters. See the user manual for the model (Johnson & Ettinger 2000) for a discussion of modeling parameters.

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBCHQ = 0.1 Site-spec VF (ug/L)	WLRW Carc. inhal. RBC Risk = 1E-06 Site-spec VF (ug/L)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/L)
Acenaphthene	83-32-9	7.04E+05		7.04E+05
Acetone	67-64-1	2.00E+06		2.00E+06
Aldrin	309-00-2	5.40E+03	3.93E+01	3.93E+01
Aluminum	7429-90-5			
Anthracene	120-12-7			
Antimony	7440-36-0			
Aroclor 1016	12674-11-2			
Aroclor 1221	11104-28-2			
Aroclor 1232	11141-16-5			
Aroclor 1242	53469-21-9			
Aroclor 1248	12672-29-6			
Aroclor 1254	11097-69-1			
Aroclor 1260	11096-82-5			
Arsenic	7440-38-2			
Barium	7440-39-3			
Benzene	71-43-2		3.41E+02	3.41E+02
alpha-BHC	319-84-6		1.30E+03	1.30E+03
beta-BHC	319-85-7			
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	5.20E+04	4.99E+03	4.99E+03
Benzo(a)anthracene	56-55-3			
Benzo(a)pyrene	50-32-8			
Benzo(b)fluoranthene	205-99-2			
Benzo(k)fluoranthene	207-08-9			
Benzoic Acid (at pH 7)	65-85-0			
Benzyl Alcohol	100-51-6			
Beryllium	7440-41-7			

PRG Values

		WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
	CAS Number	WLRW Noncarc. inhal. RBCHQ = 0.1 Site-spec VF (ug/L)	WLRW Carc. inhal. RBC Risk = 1E-06 Site-spec VF (ug/L)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/L)
Target Analyte List				
bis(2-chloroethyl)ether	111-44-4		2.34E+03	2.34E+03
bis(2-chloroisopropyl)ether	39638-32-9			
bis(2-ethylhexyl)phthalate	117-81-7			
Bromodichloromethane	75-27-4	1.62E+04	4.90E+02	4.90E+02
Bromoform	75-25-2	5.23E+04	2.54E+04	2.54E+04
Bromomethane (methyl bromide)	74-83-9	2.71E+02		2.71E+02
2-Butanone (methyl ethyl ketone)	78-93-3	4.39E+06		4.39E+06
Butylbenzylphthalate	85-68-7			
Cadmium (water)	7440-43-9			
Cadmium (food)	7440-43-9			
Carbon disulfide	75-15-0	1.83E+04		1.83E+04
Carbon tetrachloride	56-23-5		7.77E+01	7.77E+01
alpha-Chlordane	5103-71-9			
beta-Chlordane	5103-74-2			
gamma-Chlordane	12789-03-6			
4-Chloroaniline	106-47-8			
Chlorobenzene	108-90-7	6.64E+03		6.64E+03
Chloroethane (ethyl chloride)	75-00-3	3.94E+05	1.78E+03	1.78E+03
Chloroform	67-66-3		1.46E+02	1.46E+02
Chloromethane (methyl chloride)	74-87-3	4.73E+03	1.97E+03	1.97E+03
2-Chloronaphthalene	91-58-7			
2-Chlorophenol	95-57-8	1.70E+04		1.70E+04
Chromium III	16065-83-1			
Chromium VI	18540-29-9			
Chrysene	218-01-9			
Cobalt	7440-48-4			
Copper	7440-50-8			
Cyanide	57-12-5			
4,4-DDD	72-54-8			
4,4-DDE	72-55-9			
4,4-DDT	50-29-3			
Dibenz(a,h)anthracene	53-70-3			
Dibenzofuran	132-64-9			
Dibromochloromethane	124-48-1	2.88E+04	6.41E+02	6.41E+02
Di-n-butylphthalate	84-74-2			
1,2-Dichlorobenzene (o-)	95-50-1	4.49E+04		4.49E+04
1,4-Dichlorobenzene (p-)	106-46-7			
3,3-Dichlorobenzidine	91-94-1			
1,1-Dichloroethane	75-34-3	3.38E+04		3.38E+04
1,2-Dichloroethane	107-06-2		4.19E+02	4.19E+02
1,1-Dichloroethene	75-35-4	5.57E+03		5.57E+03

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBCHQ = 0.1 Site-spec VF (ug/L)	WLRW Carc. inhal. RBC Risk = 1E-06 Site-spec VF (ug/L)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/L)
1,2-Dichloroethene (total)	540-59-0			
2,4-Dichlorophenol (at pH 6.8)	120-83-2			
1,2-Dichloropropane	78-87-5	5.05E+02	2.44E+02	2.44E+02
cis-1,3-Dichloropropene	10061-01-5	1.43E+03	6.68E-01	6.68E-01
trans-1,3-Dichloropropene	10061-02-6	1.43E+03	6.68E-01	6.68E-01
Dieldrin	60-57-1			
Diethylphthalate	84-66-2			
2,4-Dimethylphenol	105-67-9			
Dimethylphthalate	131-11-3			
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1			
2,4-Dinitrophenol	51-28-5			
2,4-Dinitrotoluene	121-14-2			
2,6-Dinitrotoluene	606-20-2			
Di-n-octylphthalate	117-84-0			
Endosulfan I	959-98-8			
Endosulfan II	33213-65-9			
Endosulfan sulfate	1031-07-8			
Endosulfan (technical)	115-29-7			
Endrin (technical)	72-20-8			
Ethylbenzene	100-41-4	7.09E+04	2.41E+03	2.41E+03
Fluoranthene	206-44-0			
Fluorene	86-73-7			
Heptachlor	76-44-8	3.80E+01	6.25E-01	6.25E-01
Heptachlor epoxide	1024-57-3			
Hexachlorobenzene	118-74-1			
Hexachlorobutadiene	87-68-3	6.36E+01	1.55E+02	6.36E+01
Hexachlorocyclopentadiene	77-47-4	1.22E+01		1.22E+01
Hexachloroethane	67-72-1	1.41E+03	3.76E+03	1.41E+03
Indeno(1,2,3-cd)pyrene	193-39-5			
Iron	7439-89-6			
Isophorone	78-59-1			
Lead	7439-92-1			
Lithium	7439-93-2			
Magnesium	7439-95-4			
Manganese (Nonfood)	7439-96-5			
Mercury (elemental)	7439-97-6			
Methoxychlor	72-43-5			
Methylene chloride (dichloromethane)	75-09-2	3.79E+00	1.00E+04	3.79E+00
2-Methylnaphthalene	91-57-6			
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	1.71E+05		1.71E+05

PRG Values

Target Analyte List	CAS Number	WLW GW Volatilization RBCs at Risk = 1E-06 and HQ = 0.1		
		WLRW Noncarc. inhal. RBCHQ = 0.1 Site-spec VF (ug/L)	WLRW Carc. inhal. RBC Risk = 1E-06 Site-spec VF (ug/L)	WLRW inhal. RBC Risk = 1E-06 or HQ = 0.1 (ug/L)
2-Methylphenol (o-cresol)	95-48-7			
4-Methylphenol (p-cresol)	106-44-5			
Molybdenum	7439-98-7			
Naphthalene	91-20-3	2.63E+03		2.63E+03
Nickel (soluble)	7440-02-0			
2-Nitroaniline	88-74-4			
Nitrobenzene	98-95-3	3.05E+04		3.05E+04
4-Nitrophenol	100-02-7			
n-Nitrosodiphenylamine	86-30-6			
n-Nitrosodipropylamine	621-64-7			
Pentachlorophenol	87-86-5			
Phenol	108-95-2			
Pyrene	129-00-0			
Selenium	7782-49-2			
Silver	7440-22-4			
Strontium	7440-24-6			
Stryene	100-42-5	1.50E+05		1.50E+05
1,1,2,2-Tetrachloroethane	79-34-5	2.02E+05	6.19E+02	6.19E+02
Tetrachloroethene	127-18-4		5.44E+02	5.44E+02
Tin	7440-31-5			
Toluene	108-88-3	2.82E+04		2.82E+04
Toxaphene	8001-35-2			
1,2,4-Trichlorobenzene	120-82-1	7.55E+04		7.55E+04
1,1,1-Trichloroethane	71-55-6	8.80E+04		8.80E+04
1,1,2-Trichloroethane	79-00-5	4.93E+03	8.24E+02	8.24E+02
Trichloroethene	79-01-6	1.78E+01	2.09E+03	1.78E+01
2,4,5-Trichlorophenol	95-95-4			
2,4,6-Trichlorophenol	88-06-2			
Uranium (soluble salts)	No CASN			
Vanadium	7440-62-2			
Vinyl acetate	108-05-4	1.11E+05		1.11E+05
Vinyl chloride	75-01-4	2.29E+03	9.75E+01	9.75E+01
Xylene (total)	1330-20-7			
Zinc	7440-66-6			
Nitrate	14797-55-8			
Nitrite	14797-65-0			
Ammonium (as Ammonia)	7664-41-7			
Fluoride (as fluorine)	7782-41-4			

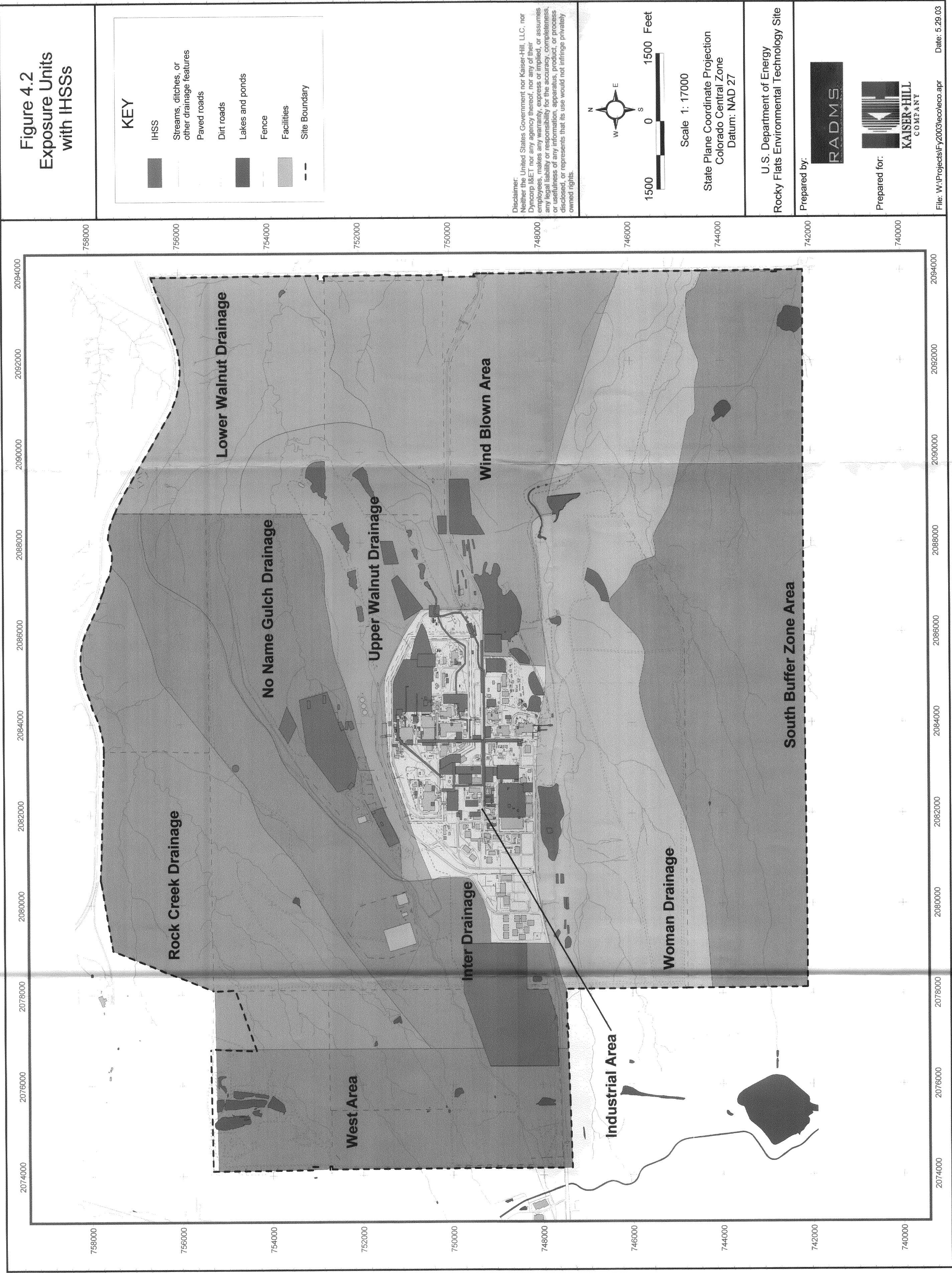
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117
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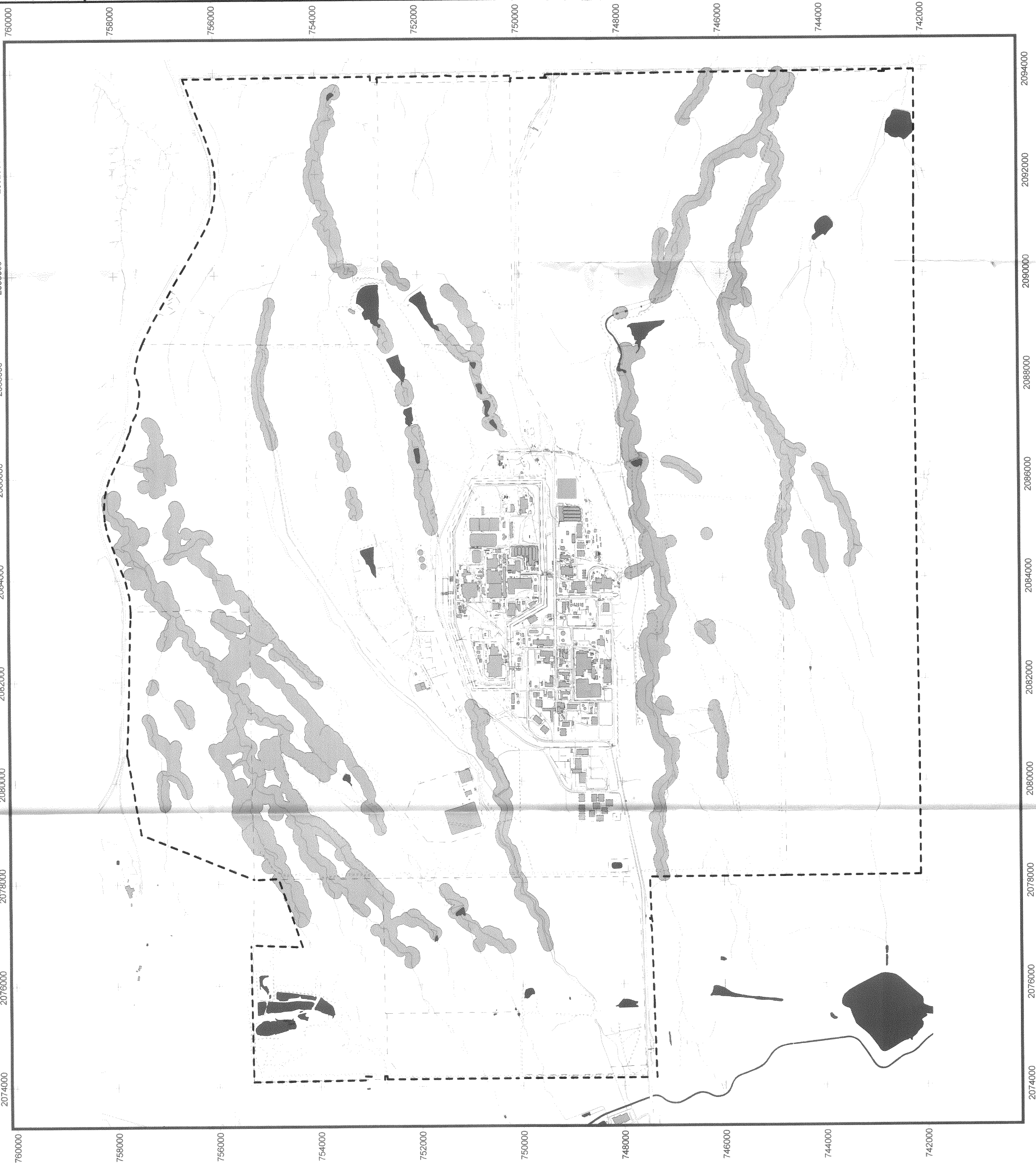
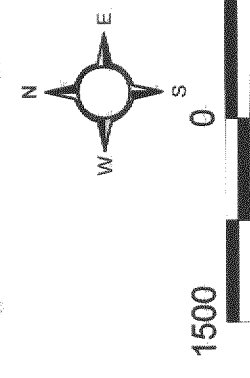


Figure 7.6
Preble's Mouse
Habitat

KEY

- Fence
- Paved roads
- Dirt roads
- Streams, ditches, or other drainage features
- Lakes and ponds
- Facilities
- Protection Area
- Site Boundary

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Scale 1: 17000
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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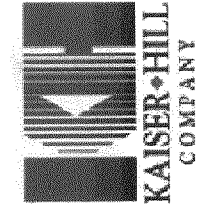
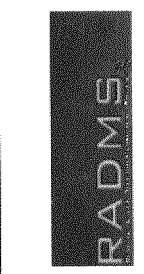
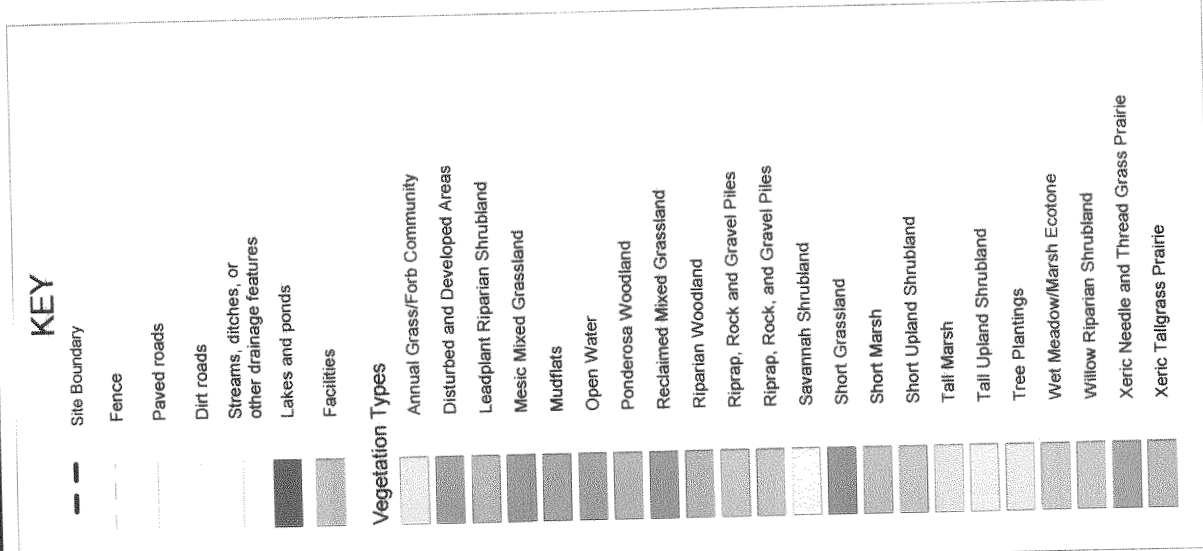
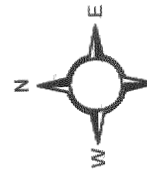


Figure 7.7
RFETS Vegetation Map



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1500 0 1500 Feet

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Prepared by:

RADMS

Prepared for:



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